DARK ENERGY HAVE WE DISCOVERED ANOTHER HIDDEN FORCE?

ALL ABOUT SPACE™

ISSUE 138
JANUARY 2023

UNMISSABLE SPACE EVENTS 2023

YOUR GUIDE TO THE NEW MISSIONS, ASTRONOMICAL EVENTS AND REVOLUTIONARY SPACECRAFT CONQUERING THE COSMOS

GET STARTED IN ASTROPHOTOGRAPHY

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ISSUE 138

SCAN HERE TO GET OUR DAILY NEWSLETTER

Ready for 2023? We are! This issue, we bring you the very best space events to watch out for throughout the next year. From meteor showers and lunar eclipses to the launches of the Psyche mission to an asteroid and the JUpiter ICy moons Explorer (JUICE) to the king of the Solar System, there's plenty to be excited for.

This month we also uncover the likelihood of a new kind of dark energy, have our experts answer your burning questions about the universe and get you started in the hobby of astrophotography – you'll soon be shooting pro shots of a variety of targets, whether you like to capture the planets, dabble in deep-sky arts or perhaps like to mix it up and try a bit of everything. I can't wait to see what you'll create, and please send your astrophotography images to our contact details at the bottom of this page.

That's it from me. I hope you enjoy the issue and I'd like to wish you a very happy New Year. Thank you from the team and I for being part of the **All About Space** community.

See you in 2023!

GEMMA LAVENDER
Content Director

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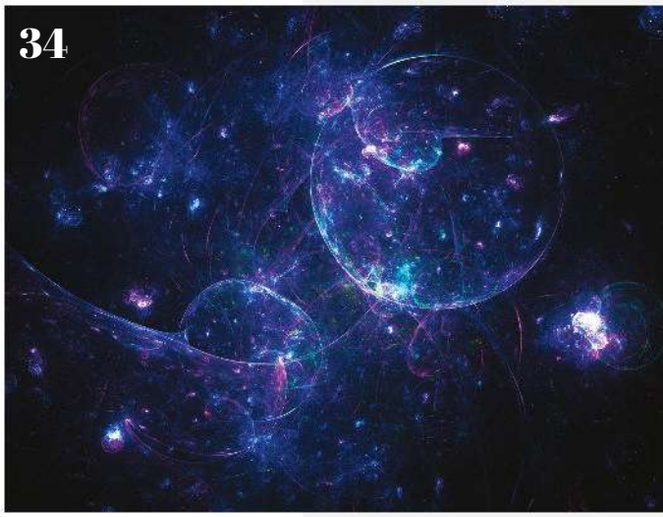

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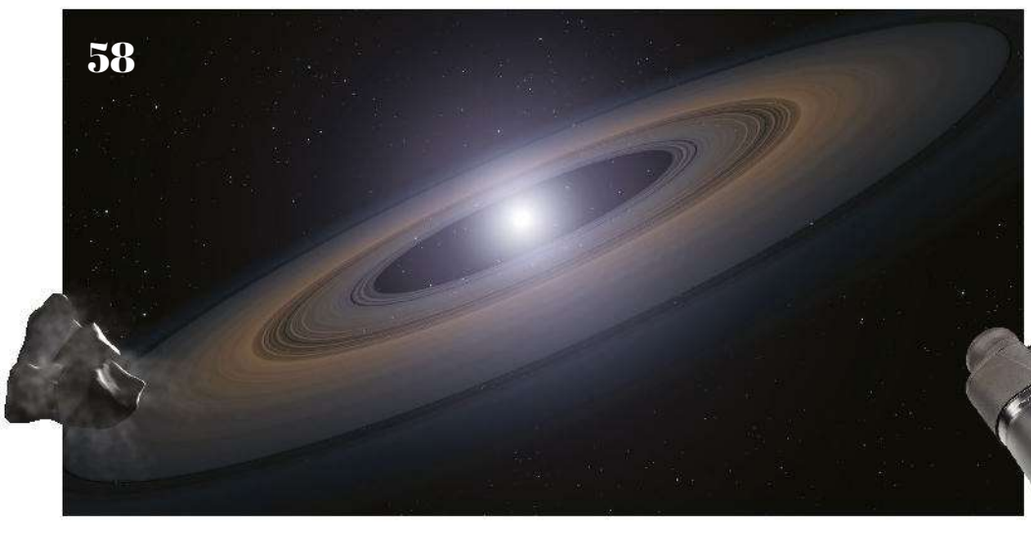

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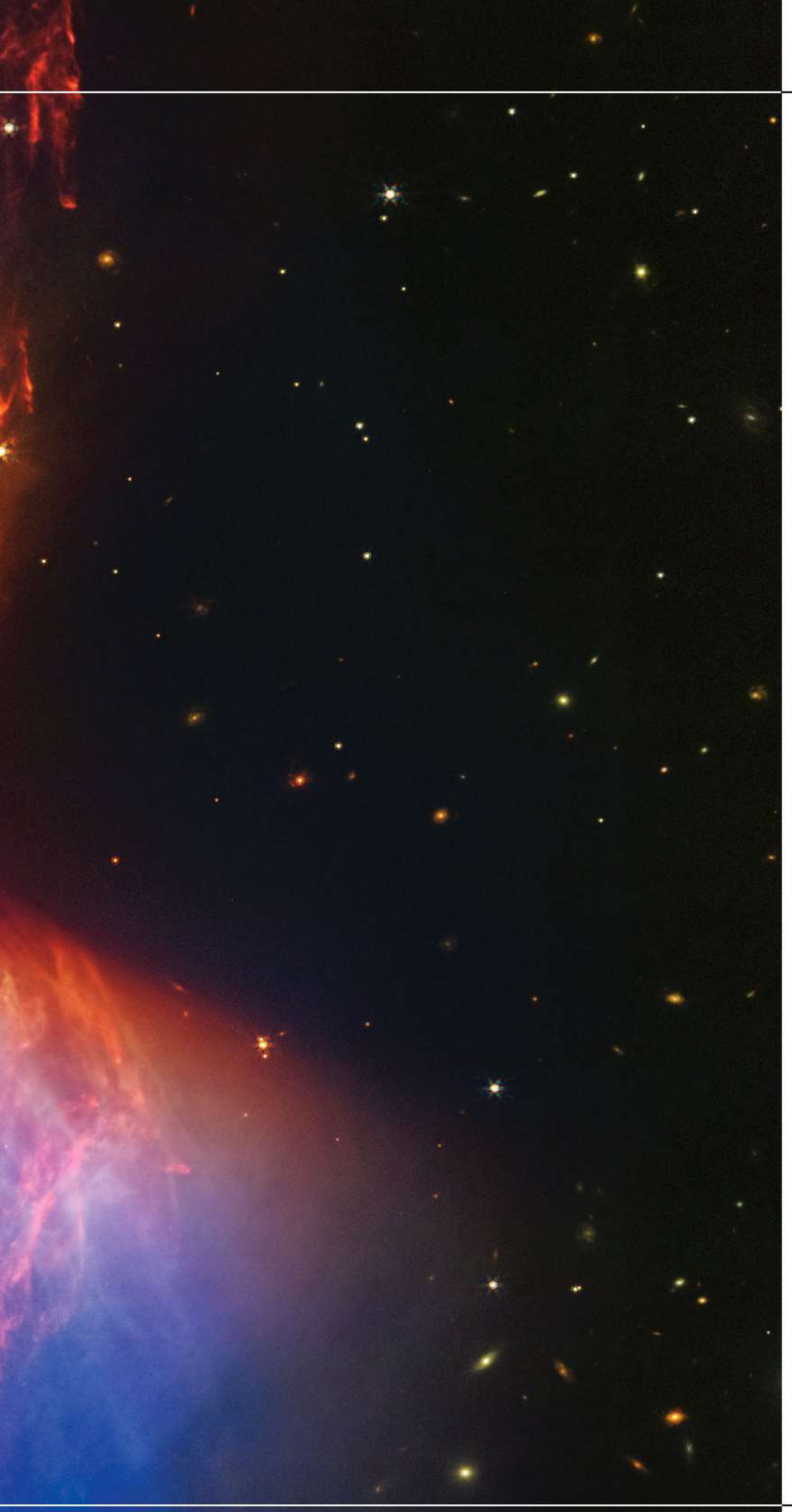

16 November 2022

Early days of star formation

The newest space telescope on the block has spotted a blazing cosmic hourglass filled with vibrant colours and hiding a fledgling star, or protostar, at its heart. The blazing formation within the Taurus star-forming region and the protostar within it have been hidden to telescopes by a dense, dark cloud of gas and dust known as L1527. The formation is only visible in infrared light, thus making it an excellent target for the Near Infrared Camera (NIRCam) aboard the James Webb Space Telescope. Astronomers hope that examining the cosmic hourglass will help illuminate the processes occurring around the protostar, which is itself hidden from view at the neck of the formation. The observations could also help explain how infant stars reach adulthood.

The protostar within L1527 and the cause of these turbulent conditions is only 100,000 years old – a mere infant in cosmic terms. Its young age and infrared brightness make the L1527 star what astronomers call a Class 0 protostar, marking the earliest stage of star formation. Class 0 protostars like this one are still cocooned within the clouds of gas and dust from which they form, and are still some way away from becoming full stars. Currently, the protostar's shape is predominantly spherical, but still unstable, and would look like a small, hot and 'puffy' clump of gas with a mass between 40 per cent and 20 per cent of the Sun.

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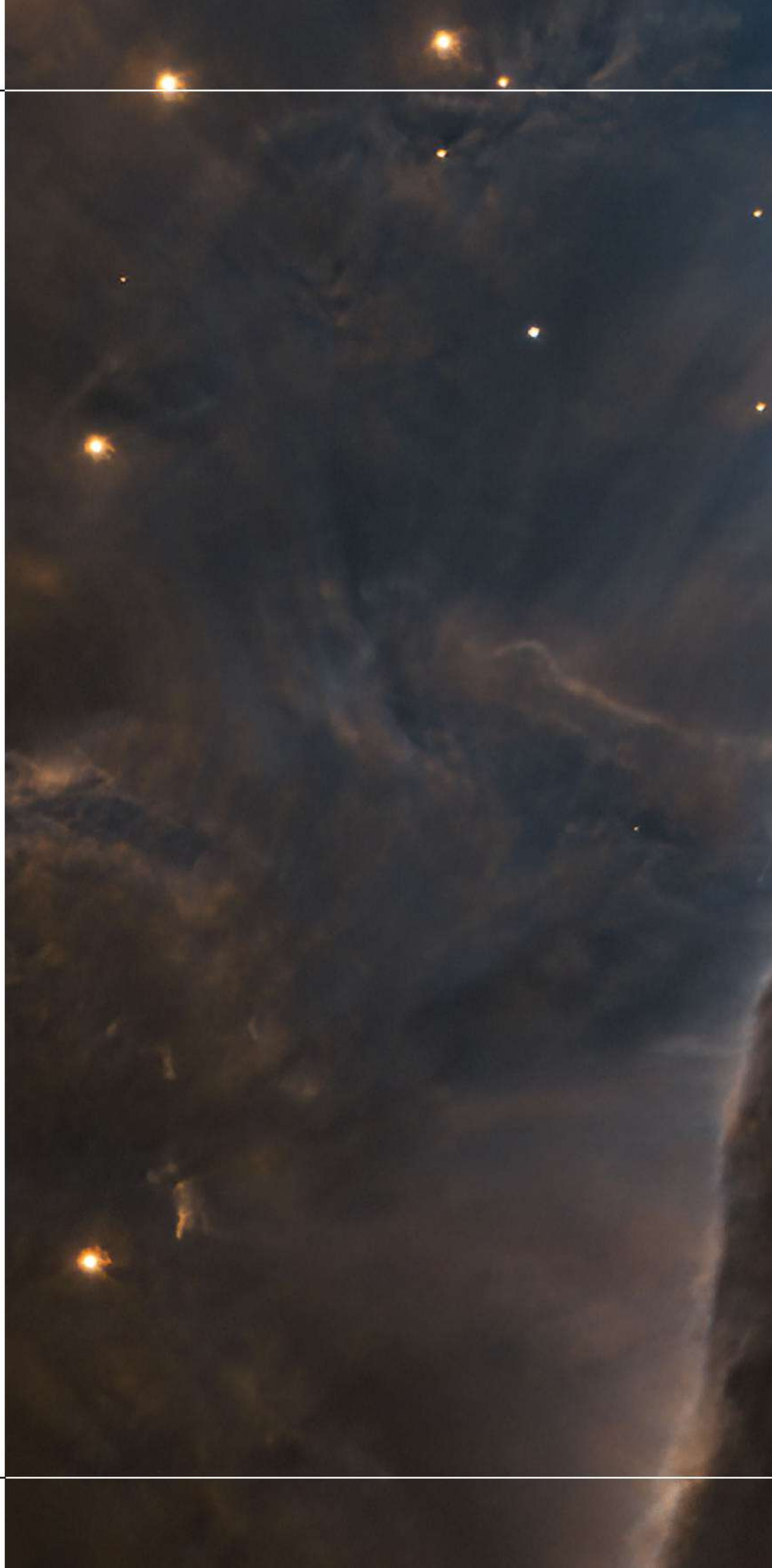

10 November 2022

New view of the Cone Nebula

A dramatic new image of the Cone Nebula shows the pillar-like cloud of cold, star-forming molecular gas and dust in unprecedented detail. The nebula gets its name from its conical shape and is located in the turbulent seven-light-year-long region of NGC 2264, which is a site of intense star formation located around 2,500 light years from Earth. Because it is relatively close to our planet, the Cone Nebula has been well studied. However, previous images lacked the incredible detail seen in the new observation, made by the Very Large Telescope (VLT) located in the Atacama Desert of northern Chile.

In the VLT image, the nebula – which is found in the constellation of Monoceros, the Unicorn – takes on a dark and impenetrably cloudy appearance, making it look, quite fittingly, almost like a mythological creature itself. Captured with the VLT's FOcal Reducer and low dispersion Spectrograph (FORS 2), hydrogen gas can be seen in blue and sulphur gas in red. Rather than appearing in their usual blue, young stars in the nebula look almost like golden sparkles.

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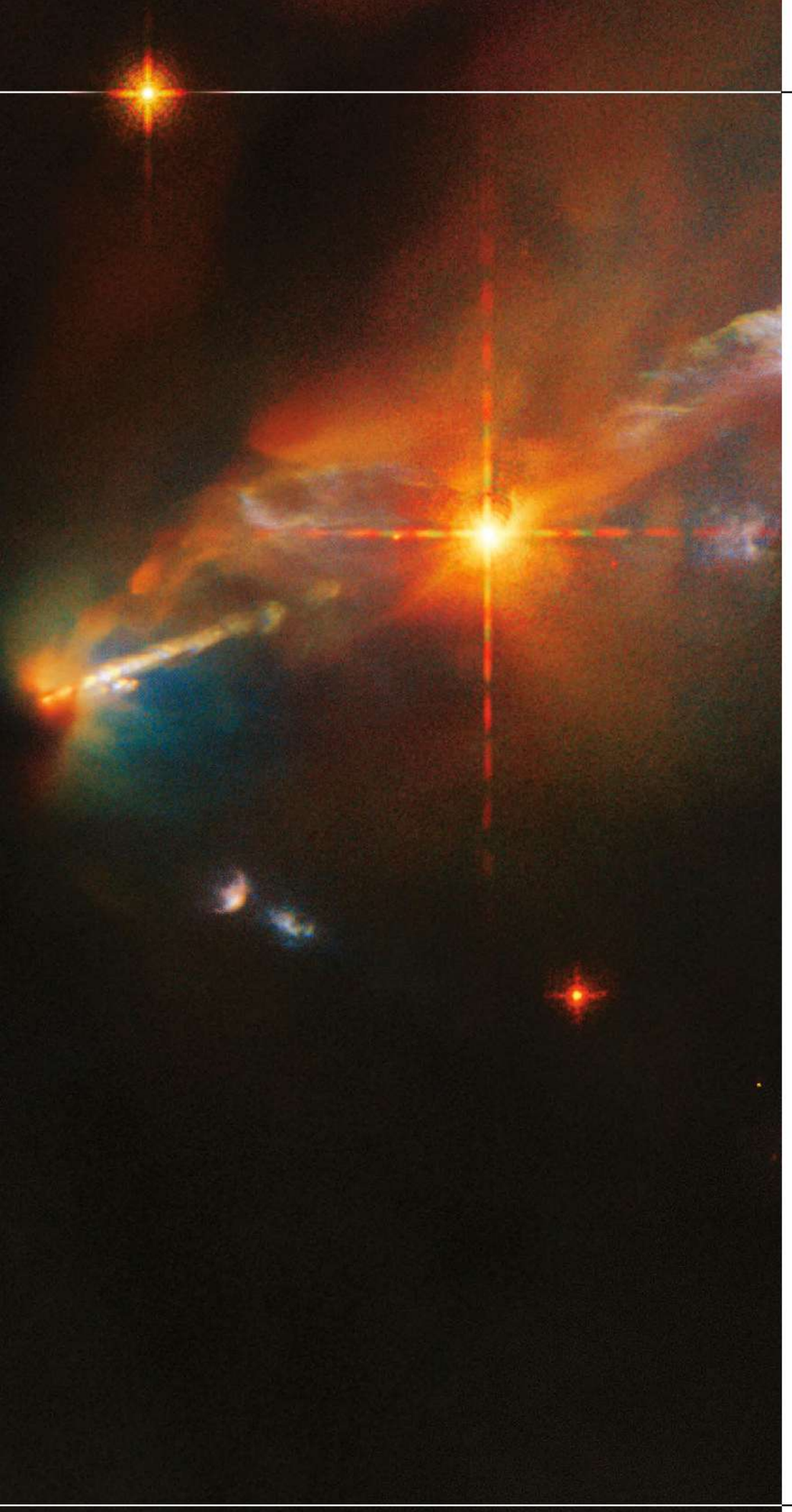


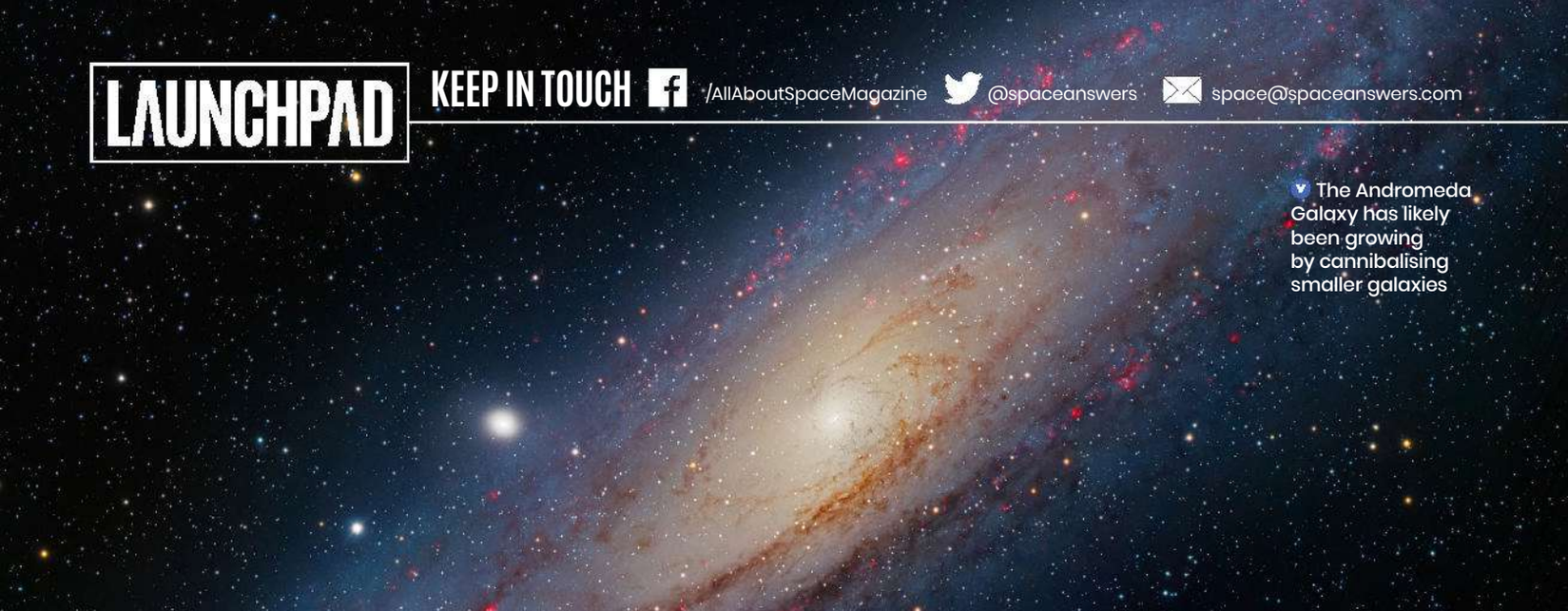
21 October 2022

Turbulent times in a stellar nursery

Two puffs of star-making material exude mystical glows in this recently published Hubble Space Telescope image. A young star system produced them, although its fledglings can't be seen here. They are shrouded in a thick layer of dust at the centre of the image. But from behind the scenes, the system casts out jets of gas at high speeds that then smack into surrounding gas and dust to form the two cloudy blasts seen on the left and right.

These structures are called Herbig-Haro objects. In 2002, astronomers found the one on the right of the image, called HH 1, has parts moving at more than 400 kilometres (248 miles) per second, expelled by the jet visible just to the right of the dark central smudge. HH 1 and its counterpart on the bottom left, HH 2, are located in the constellation of Orion about 1,250 light years from Earth. HH 1 is decorated with a double star, though this object is unrelated to the jet.

© ESA/Hubble; NASA



The Andromeda Galaxy has likely been growing by cannibalising smaller galaxies

Cosmic leftovers reveal that galactic cannibal Andromeda feasts on smaller galaxies

Reported by Robert Lea

Andromeda, the Milky Way's neighbouring spiral galaxy, may be a cosmic cannibal that has been growing by chowing down on smaller galaxies. Astronomers reached this conclusion by observing a globular cluster of stars called the Dulais Structure, named after the Welsh term for 'black stream', which now dwells in Andromeda but seems to have originated from outside the galaxy. The Dulais Structure is illuminated by star clusters that orbit unlike any other clusters in Andromeda, which means the stream of stars could represent the leftovers from a galaxy-sized meal in Andromeda's past. The findings support the idea that galactic growth happens violently and sporadically when large galaxies eat their smaller counterparts.

"We've come to realise over the last few decades that galaxies grow by eating smaller systems – so little galaxies fall in, they get eaten, it's galactic cannibalism," Geraint Lewis, an astrophysicist at the University of Sydney, said. "A few years ago, we discovered that in the far outskirts of Andromeda, there was a sign in the objects orbiting it that the galaxy hadn't been grazing, but had eaten large quantities in two distinct epochs." If this new model of Andromeda's growth is correct, Lewis said, the next question is exactly what the spiral galaxy has eaten of these smaller galaxies." That then leads to the next question of, "what was actually consumed?" he said. "Because it doesn't look like it was just one thing; it looks like it's been a collection of things that are all being slowly torn apart."

Lewis and his colleagues discovered that Andromeda shows signs of two major feeding events in its past: one meal happened sometime in the past 5 billion years, and the other was between 8 billion and 10 billion years ago. As the 13.6-billion-year-old galaxy has aged, it has expanded, meaning that during these mealtimes, matter in the universe would have been more densely concentrated than it is today. Since then, galaxies like Andromeda have formed and grown, turning the universe from a homogeneous desert of matter to the feature-filled cosmos we see today – although how precisely that played out remains unclear. "We know that the universe was featureless at its birth in the Big Bang, and today it's full of galaxies," Lewis said. "Were those galaxies born fully formed, or have they grown?"

Studying galaxies like Andromeda helps astrophysicists better understand how galaxies evolve, because seeing them from the outside offers a more complete picture than observing the Milky Way from our position within it. While there is some evidence that our galaxy has been merging with and even swallowing other galaxies, it isn't yet settled. Our Milky Way Galaxy, which is similar in size and shape to Andromeda, has also engaged in bouts of galactic cannibalism to facilitate its own growth. However, the clear picture of feeding events and growth spurts in Andromeda does show that this is occurring in the local universe. "What this new result does is provide a clearer picture of how our local universe has come together," Lewis said. "It is telling us that at least in one of the large galaxies there has been this sporadic feeding of small galaxies. What we want to know is, has the Milky Way done the same, or is it different?"

Lewis and his team now aim to pinpoint when the Andromeda feeding events occurred. This information will be important in perfecting models of galactic evolution. To determine the dates of the galaxy's meals, the researchers must understand the distances at play in Andromeda between its 'homegrown' features and the remains of consumed galaxies. This will allow the team to recreate Andromeda's history in three dimensions. "That will then allow us to work out orbits – where things are going – and then we can start to run the clock backwards and see if we can get this coherent picture of when things fell in," Lewis said.

The first indications of the Dulais Structure's origin as leftovers came in the work of two students: Tim Adams of the University of Sydney and Yuan Li of the University of Auckland. "When they come to you and say, 'I keep getting this signal, and it's a bit weird,' that's when it gets very exciting," Lewis said. "It's opened a new door in terms of our understanding. But exactly what it's telling us, I think we still have to work that one out."

NASA awards Texas company $57 million for a lunar construction system

Reported by Mike Wall

A nascent off-Earth construction system just got a big funding boost. NASA has awarded the Texas-based company ICON $57.2 million (£47 million) for its Project Olympus, which is working to develop technology that will allow humanity to build outposts on the Moon and Mars using locally available dirt and rock. "To change the space exploration paradigm from 'there and back again' to 'there to stay', we're going to need robust, resilient and broadly capable systems that can use the local resources of the Moon and other planetary bodies," ICON co-founder and CEO Jason Ballard said. "We're pleased that our research and engineering has demonstrated that such systems are indeed possible, and we look forward to now making that possibility a reality," he added.

ICON is a pioneer in the use of advanced construction technologies here on Earth. For example, the company built the first-ever fully permitted 3D-printed home in the US in 2018 and has since delivered entire communities of such houses in the US and in Mexico. The company launched Project Olympus in 2020, reasoning that it could help build critical infrastructure like landing pads, roads and habitats on the Moon and Mars. ICON has already produced a prototype of sorts – a simulated 3D-printed Red Planet habitat called Mars Dune Alpha that NASA will use to train astronauts for long-duration missions.

The newly announced NASA contract, granted via the agency's Small Business Innovation Research program, will help the company mature its technology and procedures. ICON plans to use the money to learn how lunar soil, or regolith, behaves in lunar gravity using simulated samples and real ones brought back by the Apollo missions. The company will also test its hardware and software on a space mission that simulates lunar gravity. And there will be an even more ambitious trial if all goes according to plan." The final deliverable of this contract will be humanity's first construction on another world, and that is going to be a pretty special achievement," Ballard said.

NASA's interest in lunar construction systems is no surprise; through its Artemis program, it's working to establish a sustainable, long-term human presence on and around the Moon by the end of the 2020s. The first Artemis mission, Artemis I, launched on 16 November, sending an uncrewed Orion capsule to lunar orbit. Orion is due to return to Earth with an ocean splashdown on 11 December. "In order to explore other worlds, we need innovative new technologies adapted to those environments and our exploration needs," Niki Werkheiser, director of technology maturation in NASA's Space Technology Mission Directorate, said. "Pushing this development forward with our commercial partners will create the capabilities we need for future missions."

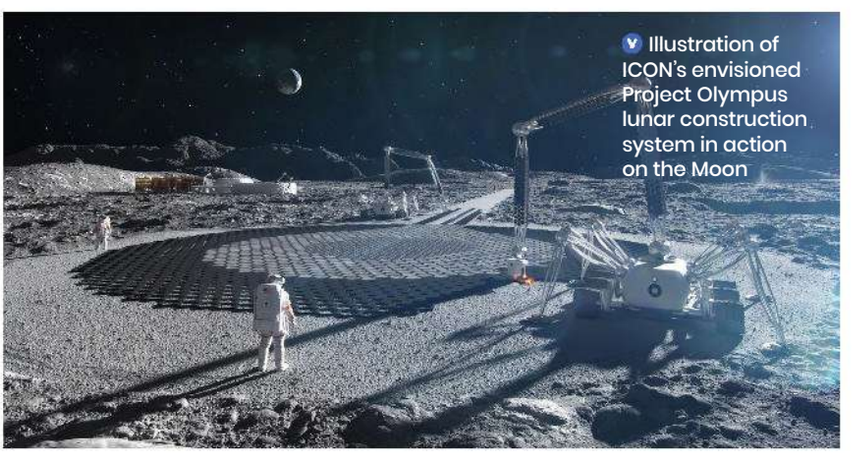


Illustration of ICON's envisioned Project Olympus lunar construction system in action on the Moon

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A lab-grown black hole may prove Stephen Hawking's most challenging theory right

An illustration of a black hole

Reported by Ben Turner

Scientists have created a lab-grown black hole analogue to test one of Hawking's most famous theories – and it behaves just how he predicted. The experiment, created by using a single-file chain of atoms to simulate the event horizon of a black hole, has added further evidence to Hawking's theory that black holes should emit a faint glow of radiation from virtual particles randomly popping into existence near their boundaries. What's more, the researchers found that most of the light particles, or photons, should be produced around the cosmic monsters' edges.

According to quantum field theory, there's no such thing as an empty vacuum. Space is teeming with tiny vibrations that, if imbued with enough energy, randomly burst into virtual particles – particle-antiparticle pairs that almost immediately annihilate each other, producing light. In 1974, Hawking predicted that the extreme gravitational forces felt at the mouths of black holes – their event horizons – would summon photons into existence in this way.

Now another atom-chain experiment has achieved a similar feat, this time by tuning the ease at which electrons can hop from one atom to the next in the line, creating a synthetic version of a black hole's space-time warping event horizon. After tuning this chain so that part of it fell over the simulated event horizon, the researchers recorded a spike in temperature in the chain.

China completes the world's largest solar telescope array, with a whopping 313 dishes

Reported by Andrew Jones

China has completed construction of what is now the world's largest array of telescopes dedicated to studying the Sun and how its behaviour affects Earth. The Daocheng Solar Radio Telescope (DSRT), located on a plateau in Sichuan province in southwest China, consists of 313 dishes, each with a diameter of six metres (19.7 feet), forming a circle with a circumference of 3.14 kilometres (1.95 miles).

The DSRT is focused on observing solar flares and coronal mass ejections (CMEs), which can interfere with or overload electronics and wreak havoc on and above Earth. CMEs are triggered by realignments in the star's magnetic field that occur in sunspots, and when directed at Earth can threaten power grids, telecommunications, orbiting satellites and even put the safety of astronauts aboard the International Space Station and China's newly completed Tiangong space station at risk.

"We can forecast whether a solar storm bursts towards Earth," Wu Lin, deputy chief designer of the Ring Array Solar Radio Imaging Telescope Project, said. "If it bursts towards Earth and will reach us, we will be able to issue early warnings to such a solar storm. In this way, we can provide space environment forecasts for normal operation of satellites in space and power grids on ground."

The colossal array will start pilot operations in June 2023 upon completion of alignment and a joint test.

Aerial view of the construction site of the Solar Radio Telescope on 13 November 2022

©NASA; Getty Images

WIN

OREGON OBSERVATION 20x80 WORTH £159

See the cosmos up close with this superb binocular

The Oregon Observation 20x80 binocular is the perfect companion for not just viewing the landscapes and wildlife on Earth, but also getting up close to the variety of planets, galaxies, nebulae and star clusters that populate our night skies. Fitted with a BAK-4 Porro prism multi-coated optical system, this exquisite binocular provides an excellent object magnification while maintaining crisp and contrasted colours. This exquisite binocular also features fold-down rubber eyecups, a soft carry case with rainguard and a wide nylon strap. Along with its integral tripod adapter socket and comfortable, long eye relief eyepieces, a long night of observing can be had with minimum effort.

To be in with a chance of winning, answer this question:

When did Artemis I, the mission to the Moon, launch?

A: It hasn't yet

B: 16 November 2022

C: 10 July 2022

Competition ends on 26 January 2023

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UNMISSABLE SPACE EVENTS 2023

There are many astronomy events and space missions to look forward to over the next 12 months

Reported by David Crookes

As regular readers of **All About Space** will know, a month doesn't pass by without some exciting space-related news. Whether it's a new mission launch, astonishing scientific discoveries or simply another eye-opening image, there's always plenty to discuss and enjoy. It's what keeps us looking to the skies in wonder. In 2023 there is much to look forward to. As well as annual astronomy events, we'll see the private space sector making more of an impact and ever more countries making their mark. There will be missions to planets and moons, scientific results to digest and potential discoveries that could make us rethink what we know. Let's get stuck in and see what's coming our way and ensure telescopes are at the ready to keep an eye on the sky. Don't forget that we'll be here each month throughout the year to cover every event in greater detail. Here's to a great year.

February

INDIA STARTS TEST FLIGHTS

India's national space agency is looking to send a three-member crew into space, so will be launching an imminent test flight of its Gaganyaan spacecraft. It will launch on a GSLV Mark III rocket from Satish Dhawan Space Centre in Sriharikota, sending the capsule skywards for a few hours. The hope is that Indian astronauts will eventually spend up to seven days in low-Earth orbit at a distance of 400 kilometres (250 miles) in what would be the Indian Space Research Organisation's first manned space mission. But before that happens, there will be a minimum of 17 different tests. Once a crewed mission is given the go-ahead, India hopes to continue building up into a major space power and potentially even open the possibility of space tourism in the country.

- The Indian spacecraft is designed to carry three people
- Polaris Dawn will see the first commercial spacewalk

March

PRIVATE CITIZENS CONDUCTING ORBITAL EXPERIMENTS

SpaceX's Polaris Dawn human spaceflight mission is seeking to reach the highest Earth orbit ever flown, but it's going to be just as notable for who will be on board. Billionaire Jared Isaacman, Anna Menon, Scott Poteet and Sarah Gillis are private citizens set to complete the first-ever commercial spacewalk. They will lift off in a Crew Dragon capsule atop a SpaceX Falcon 9 rocket from NASA's Kennedy Space Center in Florida and reach an initial apogee of 1,400 kilometres (870 miles). They'll perform the spacewalk at an altitude of 700 kilometres (435 miles) and conduct 38 science and research experiments during the five-day mission. Each is designed to learn more about the human body on both Earth and in space.

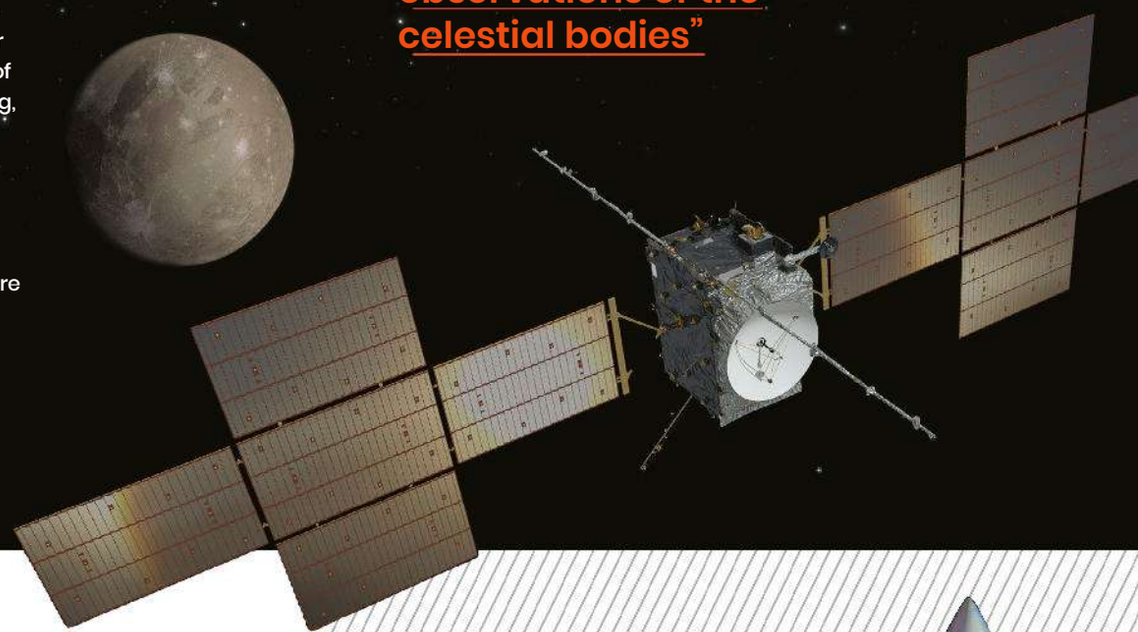
© NASA; Getty; Indian Space Research Organisation; Polaris Program / John Kraus

April

EXPLORING JUPITER

The European Space Agency is looking to orbit the gas giant Jupiter and three of its icy moons – Europa, Callisto and Ganymede – but it's going to take at least seven years to get there. Launching from Europe's spaceport in French Guiana, the mission known as the JUpiter ICy moons Explorer (JUICE) will make detailed observations of the celestial bodies using remote sensing, geophysical and in-situ instruments. After gaining information about Jupiter's atmosphere and magnetosphere, it will eventually become the first craft to orbit Ganymede – the only Solar System moon with its own magnetic field – before crashing into its surface.

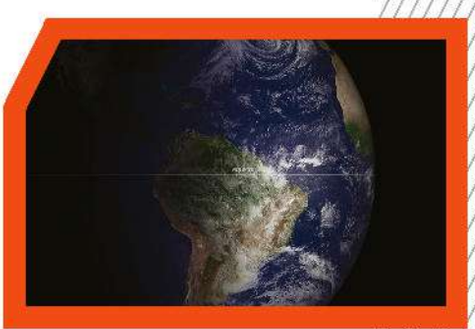
"JUICE will make detailed observations of the celestial bodies"



20 March | 22 September

WHEN DAY AND NIGHT ARE EQUAL

There are two equinoxes each year. The first occurs on 20 March at 10:29, marking the first day of spring in the Northern Hemisphere and the first day of autumn in the Southern Hemisphere. The second is on 22 September at 20:02, and that marks the first day of spring in the Southern Hemisphere and the first day of autumn in the Northern Hemisphere. Earth is tilted on its axis by an angle of 23.4 degrees, so as it orbits, the position of the Sun in the sky changes. In March, the Sun crosses the equator from south to north, and in September it crosses from north to south. The equinox is the moment when the Sun is directly above the equator, causing day and night to be equal across the planet.



Day and night are equal twice a year on the equinoxes

April

AUSTRALIA'S FIRST ROCKET

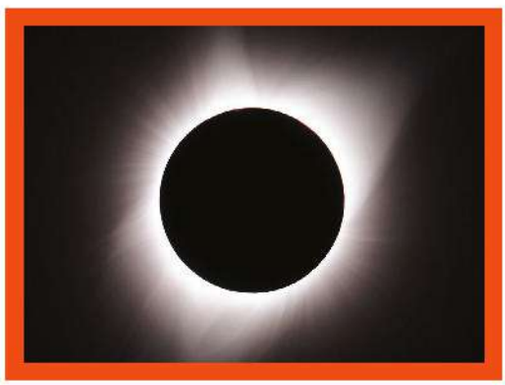
Australia has never sent a rocket of its own into space, but that's about to change. So long as the private company Gilmour Space Technologies is able to put the finishing touches on its 30-tonne Eris orbital launch vehicle in March – and with more than 3,000 components, that's no mean feat – it'll be able to test launch it the following month from a site in Queensland. In doing so, the 25-metre (82-feet) tall, two-metre (6.5-feet) diameter three-stage rocket will put a 305-kilogram payload into low-Earth orbit. If everything goes off without a hitch, it'll be only the 12th country to send a homegrown orbital rocket into space.

The craft is due to launch from Bowen Orbital Spaceport in Abbot Point

20 April

HYBRID SOLAR ECLIPSE

One of the most spectacular astronomical events has to be the total solar eclipse – that perfect moment when the Moon passes between the Sun and Earth. It causes the face of the Sun to be blocked from sight, and the sky turns dark as a result. If you want to see one this year, you'll need to head to Exmouth, Western Australia. That's the spot where, at 11:27, you'll get to see a total eclipse in all its peak glory for 62 seconds. But that's not all. The whole event – which Australians are calling the Ningaloo Eclipse – is actually a hybrid solar eclipse, and it's the first in Australia for more than 1,000 years, since they only occur a few times each century. It's a combination of a total solar eclipse and an annular eclipse, where the Moon blocks the centre of the Sun but allows a circle of light to show. If you're lucky enough to see it, you just need to remember to wear appropriate solar eclipse glasses so that the Sun doesn't damage your eyes.



The first Axiom mission flew in April 2022

Australia's last total eclipse was on 13 November 2012

Mid-2023

AXIOM SPACE CONDUCTING FURTHER ISS EXPERIMENTS

Having already sent a privately funded and operated human crewed mission to the International Space Station, Axiom Space is due to do it all over again. Four people will journey towards the ISS atop a SpaceX Falcon 9 rocket, and they'll make their way to and from the space station in a Dragon capsule. Spending ten days on board, they'll conduct research and investigate novel technologies. The hope is that they will also demonstrate the benefits of commercial space missions. At the time of writing, we still don't have the names of all the crew members – notably the two who are from Saudi Arabia. But retired NASA astronaut Peggy Whitson will be in command, who has spent more days in space than any other American in history. She'll be joined by a race car driver and airshow pilot called John Shoffner, who paid for his place in May 2021. He was the backup pilot for Axion Mission 1 and will be piloting the forthcoming mission.

Mid-2023

VIRGIN GALACTIC BEGINS SPACE TOURIST FLIGHTS

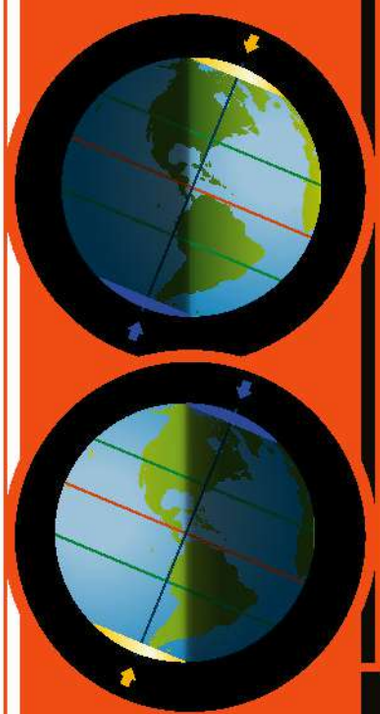
At some point in the second quarter of 2023, Virgin Galactic will hopefully get its commercial suborbital spaceflights off the ground. Using a SpaceShipTwo spacecraft called VSS Unity, four passengers will be taken to an altitude of 16 kilometres (ten miles) attached to carrier aircraft before being allowed to shoot skywards at three-and-a-half times the speed of sound to the edge of space. Once the spacecraft rocket motor has been shut down, the passengers will unbuckle their seatbelts, feel the effects of microgravity and take in the stunning views of Earth, with the overall journey lasting 90 minutes. Tickets aren't cheap, costing up to $450,000 (£368,000), and the trips are sold out for the time being. But Virgin Galactic aims to embark on as many as three flights per month at some stage while also making use of a six-passenger vehicle called VSS Imagine.

© NASA/ESA/JPL; Getty; Gilmour Space Technology; Virgin Galactic

21 June | 21 December

THE LONGEST AND SHORTEST DAYS OF THE YEAR

Although it reduces the opportunity to stargaze, the two annual solstices are nevertheless celebrated. On these days, the Sun is reaching its highest and lowest points in relation to Earth, resulting in two very different situations north and south of the equator. On 21 June the North Pole is tilted towards the Sun, with the Northern Hemisphere experiencing its longest day in terms of the number of hours of daylight and the Southern Hemisphere experiencing its shortest day. On 21 December the South Pole is tilting towards the Sun and the opposite happens. Many gather at Stonehenge in Salisbury, England, to celebrate the summer solstice.



July

LANDING ON THE LUNAR SOUTH POLE

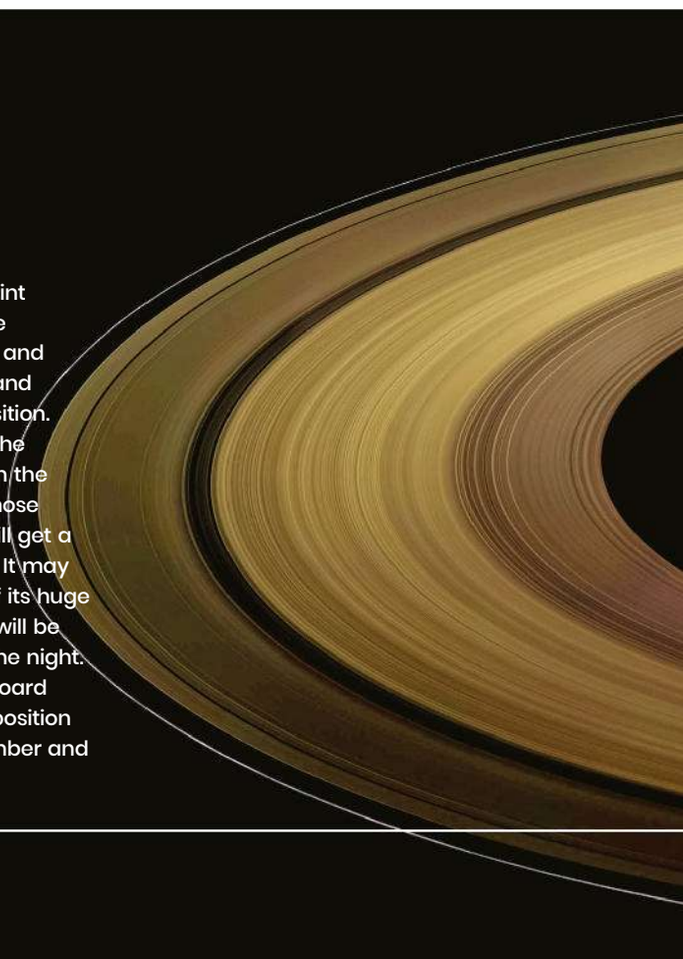
The Russian mission Luna 25 has already slipped back from 2022, but if it launches in July it'll finally put a robotic lander in the south polar region of the Moon. Touching down near Boguslavsky crater and expected to be active for more than a year, the lander will be used by Roscosmos scientists to study the upper surface layer and lunar atmosphere. It'll test soft-landing technology too. It'll also become, technically, at least, the first Russian spacecraft to land on the Moon, because the others were launched by the Soviet Union. There's a chance that the ongoing war in Ukraine could delay plans further, however, given that the European Space Agency announced it was cutting ties with the country on the Luna program. Much depends on whether the Russians have been able to replace all ESA instruments.

The first Luna probe was launched by the Soviets in 1959 – this one is much more advanced

27 August

SATURN IS AT OPPOSITION

Saturn is a stunning planet, but you may have only seen images of it. Point your telescope in the direction of the constellation of Capricorn in August and you'll be able to see it at its largest and brightest thanks to it being at opposition. This means it will be lying opposite the Sun in the sky - when our star sets in the west, you'll see Saturn in the east. Those living in the Northern Hemisphere will get a particularly good look at the planet. It may even be possible to get a glimpse of its huge moon Titan, as well. What's more, it will be possible to see Saturn for much of the night. Don't put that telescope in the cupboard when you're done. Neptune is at opposition on 19 September, Jupiter on 3 November and Uranus on 13 November.



24 September

OSIRIS-REX BRINGS BACK AN ASTEROID SAMPLE

In May 2021, the Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer (OSIRIS-REx) spacecraft completed its work. The previous year it landed on the near-Earth asteroid Bennu, having navigated a perilous path, and it gathered lots of cosmic rocks and dust for analysis by Earth-bound scientists. All that was left to do was fire up the main engines, leave the asteroid and make its way home with the bounty safely on board. All being well, it will complete the 2.5-year journey in September and the sample capsule will land via parachute in the deserts of Utah. Researchers can then begin to unlock its secrets. OSIRIS-Rex will need to make its way towards Earth at a precise speed and direction. Get the angle wrong and it will either miss or burn up.

October

LAUNCH OF NASA SPACECRAFT TO ASTEROID 16 PSYCHE

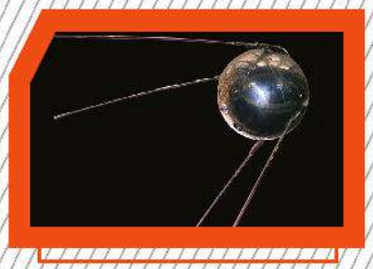
As one asteroid-faring spacecraft arrives, another sets off. In this case it's the Psyche spacecraft, which is due to embark on a journey lasting just short of six months. It'll be heading to the M-type asteroid Psyche, which was discovered on 17 March 1852 by Italian astronomer Annibale de Gasparis. It orbits the Sun in the asteroid belt between Mars and Jupiter and it's known to be composed mainly of nickel and iron. Selected in 2017 as part of NASA's Discovery Program, it will launch in a window that opens on 10 October. In 2026 it will use a Mars gravity assist, and it should arrive at Psyche in August 2029. The aim is to understand iron cores – a building block of planet formation – and to explore a new type of body, one that isn't made of rock and ice. Scientists will also get a good idea of how it was formed in relation to Earth's core and may be able to work out the age of different surface regions.

- After dropping the sample, OSIRIS-REx will head to asteroid 99942 Apophis
- 16 Psyche has a diameter of about 220 kilometres (140 miles)
- The Soviet Sputnik satellite launched the Space Race

4 to 10 October

WORLD SPACE WEEK

Since 1999, 96 countries have been celebrating an international event highlighting the benefits of space science and technology. It always takes place across the same days since 4 October marks the day in 1957 when the first human-made Earth satellite, Sputnik, was launched. 10 October is when, ten years later, a United Nations space treaty was signed. Thousands of events are held each year, and each of the weeks have been based around a theme. In 2022 it was 'space and sustainability' and in 2021 it was 'women in space', with 'satellites improve life' the year before. The theme for 2023 hasn't yet been announced yet, but bookmark the website **worldspaceweek.org** and before the time comes select a nation to see what's planned.



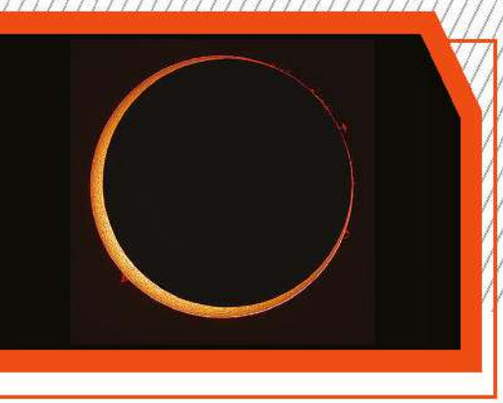
© NASA; Getty; NPO Lavochkin (www.laspace.ru)

14 October

ANNULAR SOLAR ECLIPSE

The next total solar eclipse to cross Mexico, the US and Canada won't be until 8 April 2024 – and you'll need to wait until 12 August 2026 for the next total eclipse to be visible from Europe. In the meantime, you'll be able to view an annular eclipse for the first time in 11 years, and it's just as jaw-dropping a sight. Beginning in Oregon at 9:14 PDT and ending in Texas at 12:03 CDT, it will sweep across North, Central and South America. What you'll see is a result of the Moon passing between the Sun and Earth while it's at its furthest point from our planet. Since the Moon will appear significantly smaller than the Sun at the point of crossing, you'll witness what many call a 'ring of fire'. As with a total eclipse, you should never look directly at the Sun without eye protection.

"A result of the Moon passing between the Sun and Earth while it's at its furthest point from us"



METEOR SHOWERS

Meteor showers happen every year, and you can count on most of them being spectacular. You need to be alert to catch some – the Draconids are around for a couple of days, but some last much longer. Just watch out for the peaks so that you have a better chance of seeing them. How visible they are will depend on the weather, as well as the Moon's position. You don't want the Moon to be too bright. But there are lots of opportunities to be enthralled over the coming year, and if you're located somewhere particularly dark, you're going to be truly amazed by how many you can see.

Spot a shooting star in 2023

QUADRANTIDS
Dates: 28 December to 12 January
Date of peak: 3 January
Max per hour: 120
Constellation: Boötes

LYRIDS
Dates: 16 to 25 April
Date of peak: 22 April
Max per hour: 18
Constellation: Lyra

ETA AQUARIDS
Dates: 19 April to 28 May
Date of peak: 5 May
Max per hour: 55
Constellation: Aquarius

DELTA AQUARIIDS
Dates: 12 July to 23 August
Date of peak: 30 July
Max per hour: 16
Constellation: Aquarius

PERSEIDS
Dates: 17 July to 24 August
Date of peak: 13 August
Max per hour: 100
Constellation: Perseus

DRACONIDS
Dates: 6 to 10 October
Date of peak: 9 October
Max per hour: 10
Constellation: Draco

ORIONIDS
Dates: 2 October to 7 November
Date of peak: 21 October
Max per hour: 20
Constellation: Orion

TAURIDS
Dates: 20 October to 10 December
Date of peak: 12 November
Max per hour: 5
Constellation: Taurus

LEONIDS
Dates: 6 to 30 November
Date of peak: 17 November
Max per hour: 15
Constellation: Leo

DECEMBER

CHINESE SURVEY SPACE TELESCOPE SET TO LAUNCH

China has been hard at work constructing its own space station, but it's not looking to stand still. Its next space-based endeavour is the launch of its first large space telescope, which you can either call the Chinese Survey Space Telescope (CSST) or Xuntain, the latter meaning 'space sentinel'. Expected to last ten years, it will have a primary mirror aperture of two metres (6.6 feet) and will be able to see 300 times more sky than the Hubble Space Telescope. Over its decade of use, it will capture 40 per cent of the sky and could help scientists researching dark matter and dark energy make significant breakthroughs.

December

JUNO TO FLY BY JOVIAN MOON IO

Having arrived at Jupiter in July 2016, NASA's Juno probe aimed to orbit the gas giant to better understand its atmosphere. Five years later, the mission was extended to probe some of the planet's moons, and in December 2023, Io will be firmly in its sights. Juno will make a close flyby of Io, following it up with a second pass in February 2024. NASA says it will be the first close encounter with this Jovian moon in more than 20 years and should tell scientists more about the Solar System's most volcanic body. NASA aims to study the moon's volcanoes and geology and says it will look for signs of a magma ocean and investigate how it interacts with Jupiter's giant magnetosphere. Juno will get within 1,500 kilometres (932 miles) of the moon, so watch out for some stunning imagery coming our way.

- The CSST will co-orbit with the Tiangong space station
- Io is known for its volcanism
- Skyrora was founded in June 2017

By the end of 2023

ORBITAL ROCKET TO LAUNCH FROM SCOTLAND

In August 2022, private Scottish space company Skyrora successfully tested an engine earmarked for sending satellites into orbit from Scotland. But while its subsequent first attempt to send its Skylark L vehicle above 100 kilometres (60 miles) ended in failure two months later, it still has a firm eye on a full vertical orbital launch in 2023. The UK is certainly ambitious. Construction of the SaxaVord Spaceport on the Shetland Islands is on track, and it's from here that Skyrora aims to launch its three-stage rocket, Skyrora XL. A second spaceport is planned for Sutherland in the Scottish Highlands, with the aim of being the world's greenest.

© NASA/Stefan Seip; Getty; Source: Wiki Commons/ Jaimito13080; Skyrora

FUTURE TECH

ASTEROID NETS

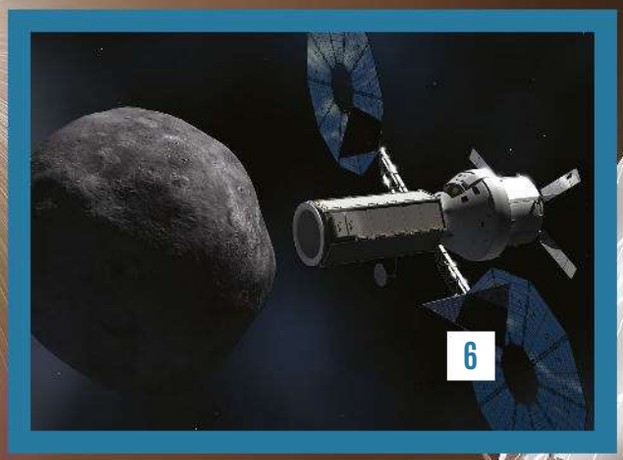
A space fishing trip could capture an asteroid and bring it closer to Earth to study

In June 2010, the Japanese Hayabusa probe succeeded in returning to Earth the first samples from a distant stoney asteroid known as 25143 Itokawa. Until recent years, such missions have rarely been successful because returning samples to Earth is very difficult. But what if the asteroid were closer? Since 2013, NASA scientists have been working on plans to identify and capture a small near-Earth asteroid – anything up to about eight metres (26 feet) in diameter – and then redirect it into a stable orbit around the Moon, where it would be accessible to Earth-based astronauts.

Current theories suggest that asteroids are part of the leftover materials from the formation of our Solar System, remaining largely unchanged since then. Having one of these pristine 'time capsules' on our astronomical doorstep would enable far more samples to be returned to Earth. It could potentially lead to numerous new scientific discoveries about the evolution of the Solar System and even the beginning of life on Earth.

Space agencies have begun to identify suitable candidates. In less than two years, NASA's Near-Earth Object Observations Program has already catalogued thousands of new near-Earth asteroids. Although the smart money is on asteroids that miss Earth, more candidates are likely to be discovered during the next few years, giving NASA experts the best choice possible. The ultimate decision will be informed by factors such as an asteroid's location, speed, orbit, size and rate of spin.

Critics have pointed out that the manned retrieval of samples is unnecessary because



thousands of meteorites have already been analysed. However, former NASA administrator Charles Bolden insisted: "Missions [like this] represent an unprecedented technological feat that will lead to new scientific discoveries and technological capabilities and help protect our home planet."

In addition, scientific offshoots will come from the development and demonstration of these asteroid-capture technologies. Principle among these is the use of advanced Solar Electric Propulsion (SEP), which creates electromagnetic fields to accelerate and expel charged atoms called ions for very low thrust and efficient use of propellant. Thanks to SEP systems, asteroid-capture missions will use between five and ten times less propellant compared to conventional chemical propellant sources. These spacecraft will provide practical trajectory and navigation experience comparable to safely landing on the surface of the Red Planet.

While the asteroid chosen will be of a size and mass sufficiently small enough to burn up in Earth's atmosphere without causing any harm, asteroid-capture missions will nevertheless demonstrate possible planetary defence techniques to deflect future space rocks that could be dangerous to Earth.

1 Assistant spacecraft
A new spacecraft like Orion could carry a crew of up to four astronauts into or beyond low-Earth orbit to the asteroid for study.

2 Rings
Hundreds of rings could be affixed to the asteroid capture bag to help the astronauts carefully navigate the surface.

3 Wrangled
A future asteroid-capture mission would trap and de-spin asteroids with a big net, tether deployer and winch, limiting excess rotation.

4 A handpicked sample
Astronauts will take samples from the captured asteroid after it has been relocated to a stable orbit in the Earth-Moon system.

5 Stopping spin
Once the asteroid is in the net, the inflatable tubes would be deflated and the winch would close, absorbing the asteroid's momentum.

6 Asteroid grabber
An alternative concept for a solar-electric-powered spacecraft with inflatable rings to capture a small near-Earth asteroid.

© Adrian Mann

BIO+

Dr Olivier Witasse

Witasse is a planetary scientist at the European Space Agency. He is the project scientist for the ESA's upcoming JUpiter ICy moons Explorer (JUICE) spacecraft, due to launch in April 2023 and arrive at Jupiter in 2031. Witasse has worked on a plethora of ESA-related space exploration missions, including Mars Express, Venus Express, Cassini-Huygens, the ExoMars Trace Gas Orbiter and Chandrayaan-1.

© Laurence Honnorat

Dr Olivier Witasse

"All missions are unique and interesting"

The European Space Agency (ESA) is preparing for its first-ever mission to Jupiter's moons. All About Space speaks to the mission's project scientist, Olivier Witasse, to find out why the Galilean satellites are so appealing

Interviewed by Lee Cavendish

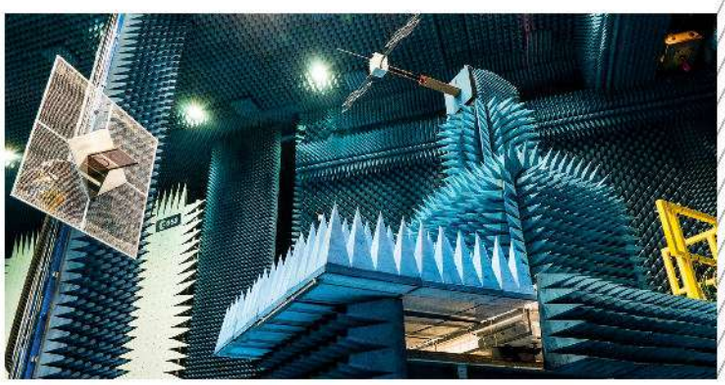
How have Ganymede, Callisto and Europa – the moons JUICE will be visiting – sustained subsurface oceans despite being so far away from the Sun? Why haven't they frozen over?

They are called 'icy moons' because they are made of frozen ice. But there is a mechanism inside the moons which generates heat, and then the ice can melt and become liquid. The question is, how is the heat generated inside? Here we have two possible reasons: one answer is that because the moons are actually large, there are – like on Earth – some radioactive elements. Inside Earth, for example, there is heat generation coming from the interior from radioactive elements. But the other process, which is quite interesting, is that because the moons are relatively close to the very big planet Jupiter, and because of the characteristics of their orbits, there is a gravitational struggle. In fact, these moons don't have the shape of a normal ball, like a football, they are more like a rugby ball. They change shape because of the gravitational attraction between the moon and Jupiter. That makes the moon change shape and keeps the interior moving. That also generates some heat, and this heat allows the ice to melt and become liquid.

How were these subsurface oceans discovered?

The discovery of subsurface liquid water was one of the greatest discoveries in planetary science, made about 20 years ago by NASA's Galileo mission. The mission went around Jupiter, and the spacecraft needed a few flybys around the icy moons and Io. With its magnetometer it discovered that there is liquid water inside Europa, Ganymede and possibly Callisto.

That was a really great discovery since the measurements were not that obvious, because, as you can imagine, we can't see it. It's inside the moon. It's done with the magnetic field. This liquid water is not pure water; it's salty water. It can change the magnetic field around the moon. And because the magnetic field around Jupiter is greater, it changes the magnetic field a bit, and we could measure this change with the magnetometer.



A scale model of the Radar for Icy Moons Exploration (RIME) in testing at the European Space Research and Technology Centre, Noordwijk

A family portrait of the Galilean moons. From top to bottom: Io, Europa, Ganymede and Callisto

Cracks on the surface of Europa could be the result of Jupiter's gravity pulling it apart

The measurement indicated that there is liquid water inside Europa. There is liquid water inside Ganymede, the biggest moon of Jupiter. And for the last icy moon, which is Callisto, there was an indication that there was liquid water, but the measurement wasn't so easy to interpret.

Why was JUICE chosen as the first large-class mission for the European Space Agency's Cosmic Vision program?

The selection took place in 2012, and for any selection of missions, whether it's NASA or the ESA or any other space agency, it's always a very complex process. There is the call for ideas for missions. Then there are some studies. Then the ESA selects the mission based on some committees, which give a recommendation, and then they make some evaluations. All in all there are a lot of discussions that address all these questions, and at the end there is a committee in the ESA which decides what is best, given all these topics.

In 2012 there were three missions in competition, and JUICE was one of them. The two others were a mission to study gravitational waves, which is now called LISA [the Laser Interferometer Space Antenna], and the third mission is ATHENA [the Advanced Telescope for High-ENergy Astrophysics], an X-ray observatory.

These three missions were in competition, and after discussing the merits of each of them, JUICE appeared to be the best one. From what we see now, to me it looks like an obvious choice, because if you see the LISA mission on gravitational waves, it's very complex from the technology point of view. You need three spacecraft with which to do laser interferometry in space. It's very complicated. ATHENA poses a lot of challenges, and we see now that those missions are not ready to launch in 2023.

You've worked on many planetary science missions, such as the NASA-ESA Cassini-Huygens mission, Venus Express, Mars Express and more. Based on your experiences, how does the JUICE mission rank in terms of originality?

All missions are unique and interesting. Every mission is selected based on some science questions that are interesting at the time of their proposal and selection. All the previous missions on which I've worked are quite interesting, and they deliver a lot of amazing results. In the case of JUICE, what is very interesting is that for Europe, it's the first time we will go to Jupiter. It's a really challenging mission. We don't go to Jupiter all the time. This kind of mission is done every 30 years or so. That's why when we manage and develop such a mission, we try to address all the possible science questions at Jupiter. In terms of science return, and interdisciplinary science, it's really great because we address all kinds of questions. We're going to study the interior of the moons, their surfaces, their atmospheres, the link between the moons and Jupiter. We'll study Jupiter and the dust around Jupiter and the question of habitability.

The most interesting question that JUICE will address is the question of why we have this liquid water inside these moons of Jupiter. That's a question that we would like to understand better, because a very important objective of planetary science and astrobiology is to find possible places for life besides Earth. This is because we'd like to know if life can develop somewhere else besides Earth. That's the big question in science.

There are going to be ten scientific instruments on board this spacecraft. Would you be able to single out two or three that you think will yield some exciting results?

As I said, we don't go to Jupiter every year, so once we reach such a mission we try to put the best instruments on the spacecraft. When the

ten instruments were selected, we tried to select the best possible payload for such an ambitious mission. In this case the payload was selected so that all the instruments could complement each other. If you want me to select two or three, I would say the camera, JANUS [Jovis, Amorum ac Natorum Undique Scrutator], will be very interesting because it will deliver fantastic images not only of Jupiter, but of the surfaces of the moons at high resolution. It can image the surface better than ten metres (33 feet) per pixel, which means we will really know what's going on on the surface, and it's always nice for the general public and the geologists and scientists in general.

Because we discussed the internal subsurface ocean, we have the magnetometer [J-MAG]. With the magnetometer we will detect the tiny variations of the magnetic field due to this ocean and we'll be able to – certainly in the case of Ganymede – know the depth of this ocean. We don't know if the ocean is ten kilometres [6.2 miles], 40 kilometres [24.8 miles] or even 50 kilometres [31 miles] deep, and we want to know the amount of liquid water. The magnetometer will give us this information, and information on the composition.

Another is the laser altimeter, GALA [Ganymede Laser Altimeter]. We will send lasers to the face of Ganymede and understand the little variations in altitude of the surface. This can help identify mountains or canyons and so on, but it will also see the variation of the change in the shape of the moon.

How much water is estimated to be in these icy moons compared to the amount on Earth?

What is amazing, surprising and fascinating is that we think there is more liquid water inside each moon than on Earth. We know the depth of our ocean is approximately ten kilometres [6.2 miles] maximum. But inside the icy moons the oceans are believed to be very big. They could be 50, 100 or even 200 kilometres [30, 60 or 125 miles] deep. That's much more than the little ten kilometres [6.2 miles] from the surface of Earth. For example, at Europa it's possible there is twice the amount of liquid compared to Earth, and for Ganymede maybe five times.

"When we manage and develop such a mission, we try to address all the possible science questions at Jupiter"

What does this mission mean for our understanding of how the Solar System formed, and do you think this will completely change our definition of what a habitable world is?

First we are going to collect images and all the data in order to understand the system as it is now. Then, based on that, as a group of scientists we can do what we like to call the 'big picture'. We collect all the data and then extrapolate it through time, do some modelling, think about it and come up with some theories. Then we can get information on the origin of the moons.

It's very difficult to know what we can get out of the JUICE data, but I'm pretty sure that when we have the data from all the systems there will be an interesting outcome in terms of moon formation and origin. As for the habitability, that will depend firstly on confirming that they have liquid water. Once we have confirmed that there is liquid water, with the dataset we are going to characterise these oceans. For example, how deep are the oceans? What are the compositions? Where are they under the surface? Are they very close to the surface or are they very deep inside the moons? All this information will be fed into the study of habitability, because the habitability of the oceans will depend on all these different factors.

A Future exploration of the moons could see an instrument drilling through the surface

B The spacecraft's 10.5-metre (34-foot) magnetometer is just one of ten state-of-the-art instruments

© ESA-NASA/JPL-Caltech; Adrian Mann

FOCUS ON

NASA'S PERSEVERANCE ROVER OPENS A WINDOW TO MARS' WATERY PAST

The Perseverance rover is approaching its one-year anniversary since landing on 18 February 2021

Reported by Briley Lewis

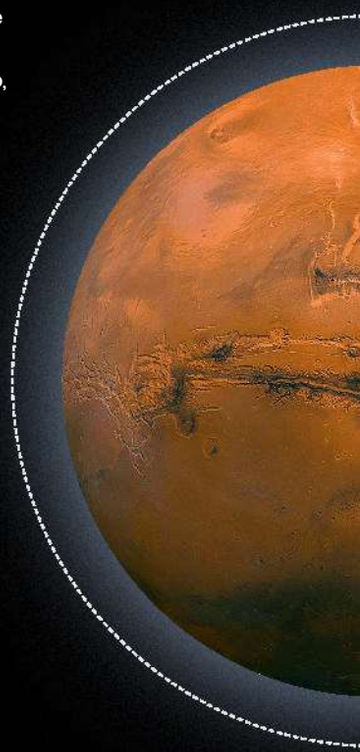
NASA's newest rover has roamed multiple miles around the Red Planet's Jezero crater, searching for signs of ancient life and hints about Mars' past. The rover, part of NASA's ambitious Mars 2020 mission, has been collecting a huge amount of information about the Martian surface and its rocks. The team behind the Perseverance rover has published three new research papers detailing their findings so far. The data reveals a "story of fire and water" in Mars' history, said Briony Horgan, a planetary scientist at Purdue University in Indiana and co-author of one of the new studies.

Perseverance is NASA's most advanced rover yet and can study Martian rocks in greater detail than any predecessor. Its suite of instruments includes the Mastcam-Z, the 'eyes' of the rover that allow it to study rocks at a distance, as well as two pieces of technology that perform X-ray and ultraviolet spectroscopy, analysing in detail the make-up of rocks and minerals. "These papers demonstrate the power of the Mars 2020 payload," said Horgan. "By studying the geology of Jezero from outcrop scales with Mastcam-Z all the way down to individual grains, we've been able to piece together the complex history of the crater floor."

For decades, satellites like the Mars Reconnaissance Orbiter have been scouting the Martian surface for interesting places to explore. The area around Perseverance's landing site in Jezero crater is particularly interesting to astronomers, since they suspect it used to be a river delta that emptied into a lake contained within the crater itself.

Water has been a long-standing point of interest on Mars, from Mariner 9's first images of the water-carved canyon of Valles Marineris in the 1970s to direct evidence of water ice dug up by landers like Phoenix in 2008 and beyond. Humans are naturally obsessed with water, since it's such a key ingredient for life – whether that's finding alien life or supporting our own during human space travel. Although it's well-established that Mars had some water at some point, planetary scientists are still trying to figure out the details of the timeline and just how much water was flowing. "By landing at Jezero, we're studying rocks that are much older than at other previous landing sites, helping us understand the most ancient times in Mars history, when we think it was the most habitable," Horgan said. "Our data confirms that water was everywhere."

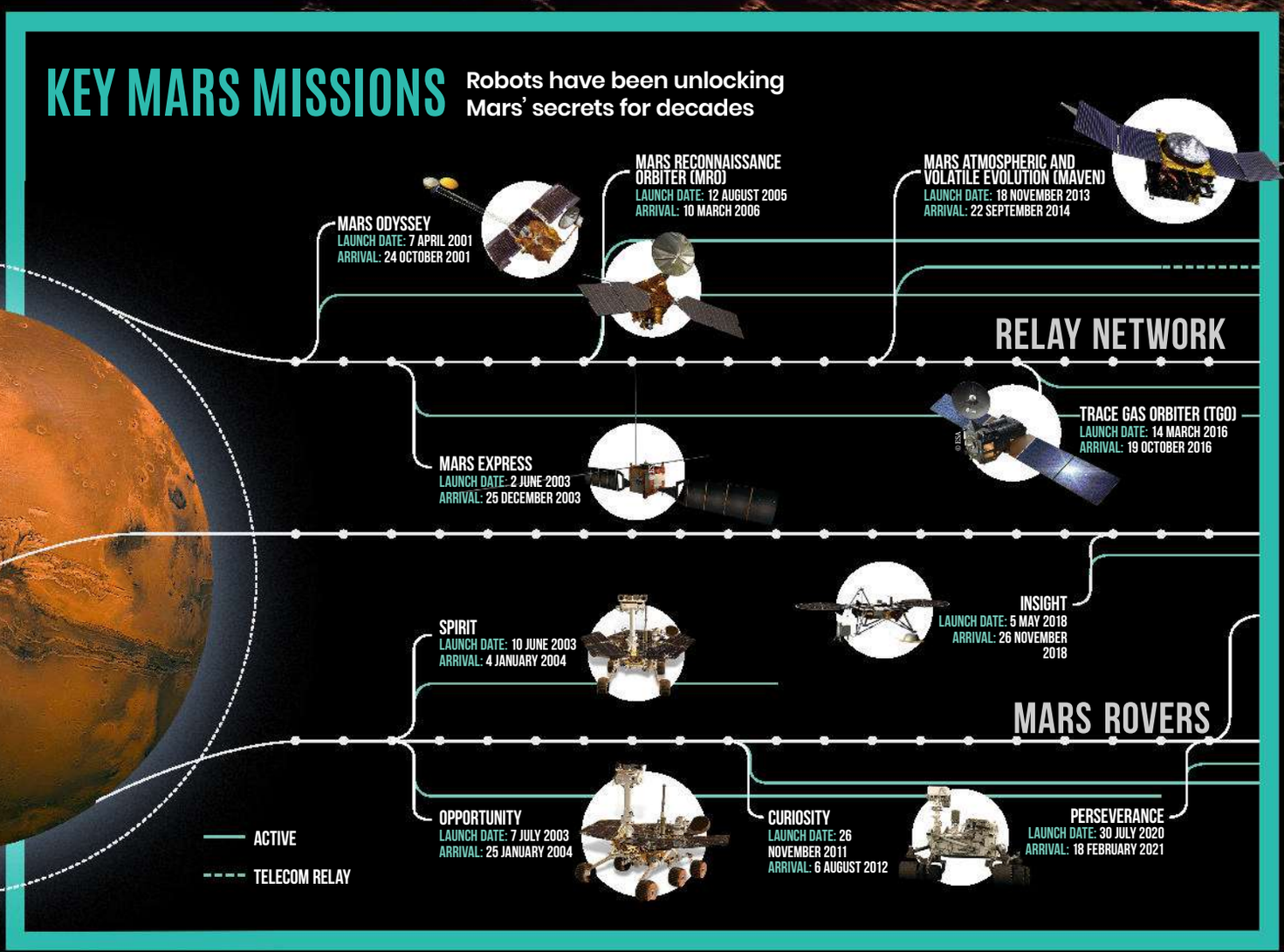
The rover found a combination of iron-rich minerals like olivine and pyroxene, which are usually found in volcanic rocks, plus versions of the minerals that had been altered by water and brine, like hematite. The chemistry of these minerals tells a story of flowing lava that encountered water multiple times. The first time water flowed, it was warm – and later the water was salty. This water could have taken the form of lakes, or maybe even groundwater flowing through the rocks. "The results from these studies demonstrate the unique capabilities of the Perseverance rover," agreed Schuyler Borges, a planetary scientist at Northern Arizona University who studies Martian analogues on Earth and who is not involved with the Perseverance team. Scientists are particularly excited about the fact that water appears multiple times in Mars' past, since more water means "more opportunities for life to be involved if it exists."



Perseverance also carried two bonus missions with it to demonstrate new technologies: the Mars Oxygen In-Situ Resource Utilization Experiment to create oxygen from the Martian atmosphere and the Ingenuity helicopter. Although Ingenuity was originally meant to prove that human technology can fly on another planet, it has evolved "from just a successful technology demonstration to a helpful bird's-eye-view science scouting companion to the rover," said Corrine Rojas, an engineer on the Mastcam-Z at Arizona State University.

Data from the rover's observations of the Ingenuity flights even provided the team with more information on how dust from the Martian surface moves – some exciting "bonus science," as Rojas called it, mentioned in these new studies. This is just the beginning for Perseverance, and it's even been prepping for the more distant future by storing samples of rock as it traverses the Martian surface. One day, NASA and its European counterpart plan to retrieve those samples and bring them back to Earth for further study. "We've learned so much," Horgan said of the mission so far. "But of course the huge advances will come when we bring these samples home."

"Our data confirms that water was everywhere"
Briony Horgan



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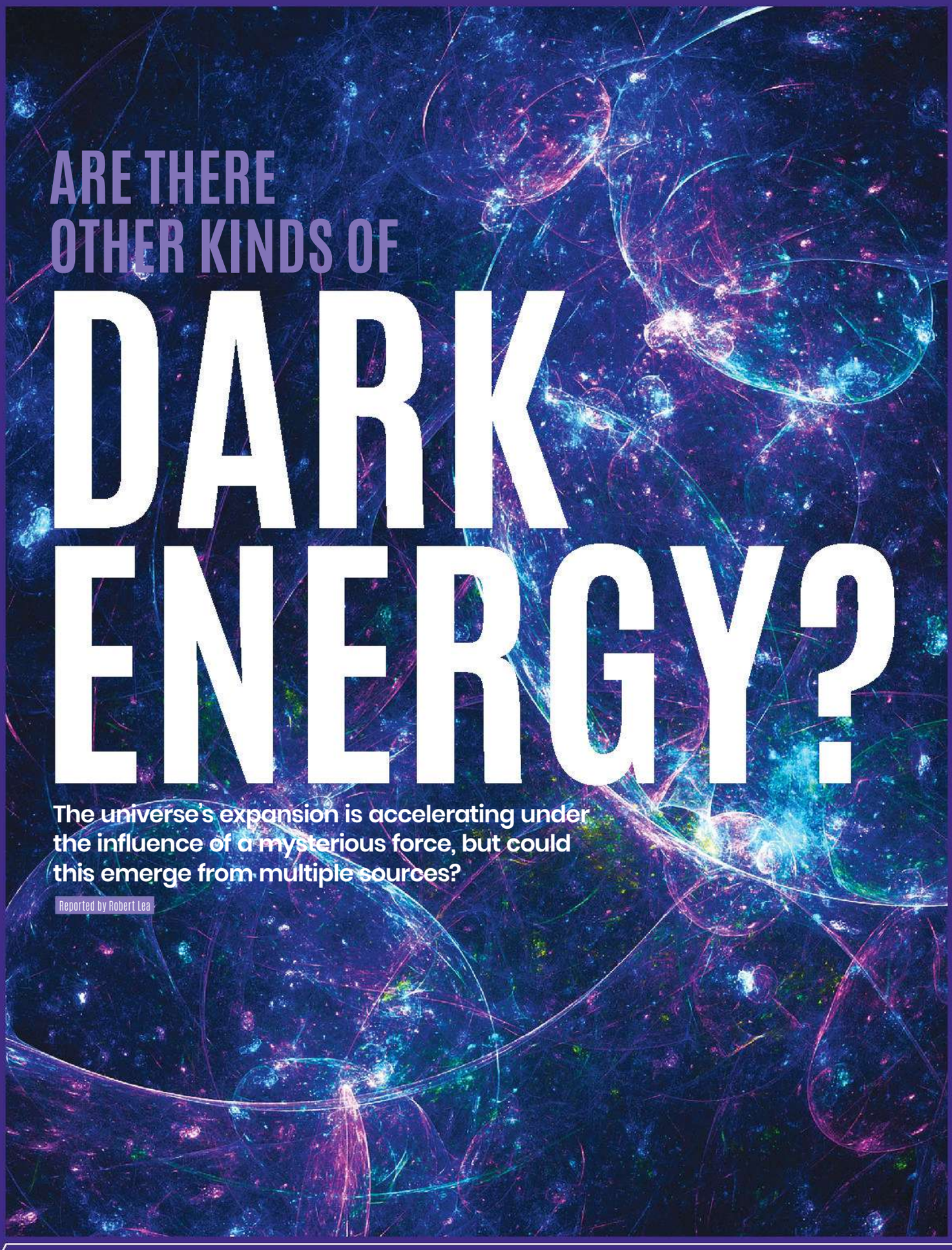
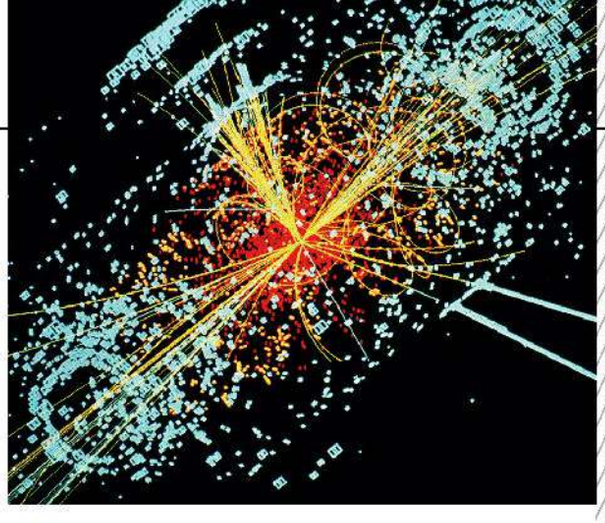


ARE THERE OTHER KINDS OF DARK ENERGY?

The universe's expansion is accelerating under the influence of a mysterious force, but could this emerge from multiple sources?

Reported by Robert Lea



The Higgs boson should make a far greater contribution to the cosmological constant than measured

The CMB, leftover radiation from an event in the early universe, confirms the accelerating expansion

The expansion of the universe is a phenomenon that can only really be measured by observing galaxies separated by massive gulfs of space. The further apart they are, the faster they race away from each other. And that effect is speeding up. Dark energy is the name given to the hypothetical force that is causing this acceleration. Think of it as gravity's counterpart, providing a negative pressure that fills the universe and drives objects apart at an increasingly rapid rate. But dark energy doesn't seem to work on objects as gravity does. It preys on the very fabric of the cosmos itself – expanding the very space between objects.

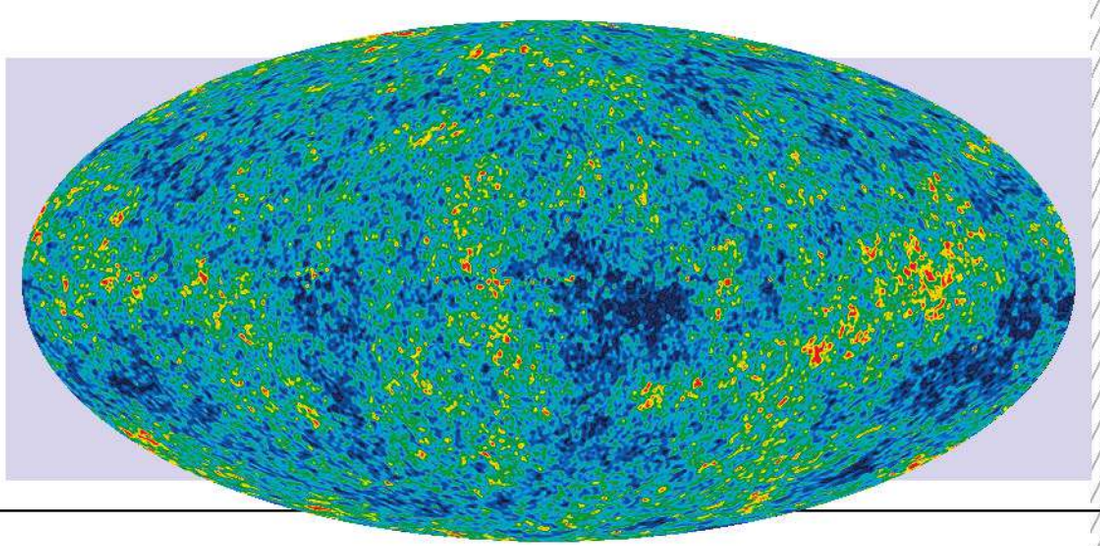
Despite the fact it accounts for roughly 68 per cent of the universe's total energy, we know very little about this mysterious repulsive energy. We aren't completely in the dark about dark energy's 'secret identity', however. Cosmologists are aware of a number of 'prime suspects' that could account for its effects. "The leading candidate is the cosmological constant, or lambda, which we associate with the vacuum of space's energy," Luz Ángela García, a physicist at Universidad ECCI in Bogotá, Colombia, explains. "Other possible candidates are quintessence fields, proposed in the early 21st century to establish a 'fifth force' responsible for the negative pressure that might cause the accelerated expansion of the universe."

García, whose work involves finding alternative models to describe dark energy, as well as testing characteristics of this mysterious force, continues: "From this fifth force, many flavours of these fields have appeared in the literature, like K–essence, tachyonic fields, phantom fields and galileons, among many others." With so many potential candidates for dark energy, it's reasonable to ask if dark energy might arise from more than one source. Yet this is a question that cosmologists are only really beginning to consider. "There's no direct evidence for dark energy emerging from more than one source," García posits. "But there is no reason to discharge such a possibility either."

Part of why scientists may have only just begun to consider a multi-source approach to dark energy could be the fact that ever since it was observed, the expansion of the universe has continued to catch researchers off guard. The discovery in the early 20th century by Edwin Hubble that the universe is expanding came as a shock to the scientific community, but really caught Albert Einstein flat-footed. Mainly because he'd already accidentally predicted and dismissed it.

When Einstein had first applied his theory of general relativity to cosmological models, the result was a contracting or expanding universe. The problem for Einstein was that he agreed with the scientific consensus at the time of a static universe. To combat

> "There's no direct evidence for dark energy emerging from more than one source"
>
> **Luz Ángela García**



THE DIFFERENT KINDS OF DARK ENERGY

The cosmological constant and vacuum energy

The leading candidate represents vacuum energy arising from 'virtual particles' popping in and out of existence in empty space. The problem is the massive difference between its theoretical value and its observed value.

The universal quantum field

Another candidate for dark energy arises from quantum mechanics. This suggests that a scalar field permeates the entire universe, replicating the acceleration effects of the cosmological constant.

The fifth force of nature

Should a universal scalar field exist, it could represent a fifth force of nature, joining gravity, electromagnetism and the strong and weak nuclear forces. This quintessence would differ from the cosmological constant by varying in time.

Multiple scalar fields

Rather than a universe with a single quantum field, how about two or three? Dark energy arising from multiple fields could help unite accelerating expansion with string theory using a low-energy universe.

Tachyonic fields, phantom energy and more

Dark energy is a complete mystery. That has resulted in a raft of plausible candidates such as tachyons – hypothetical particles travelling faster than light and backwards in time.

Modified theories of gravity

Scientists haven't completely ruled out the idea that the observed effects of dark energy and dark matter are explained by revised theories of gravity, and thus don't exist at all.

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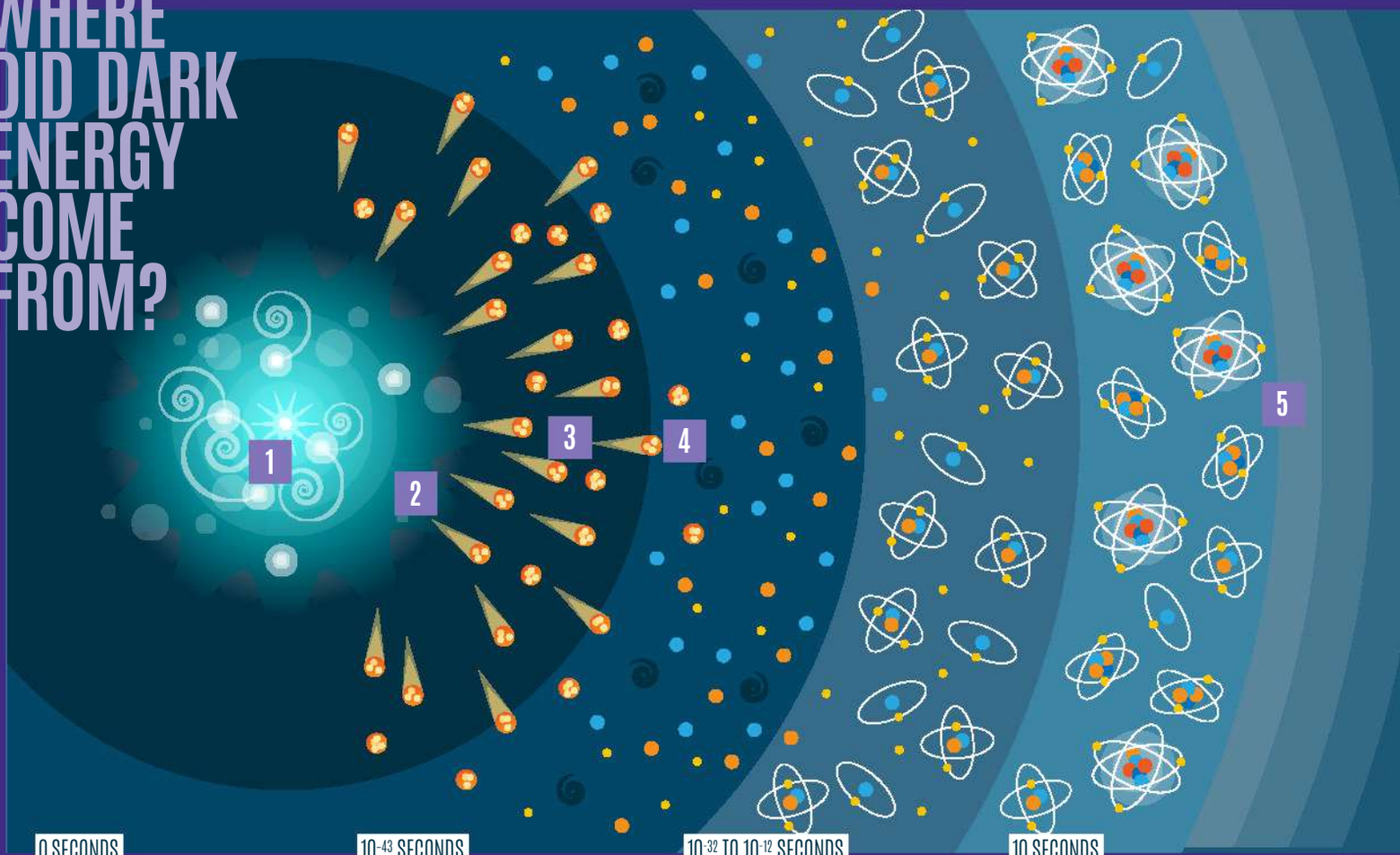
WHERE DID DARK ENERGY COME FROM?



0 SECONDS

1 Before the beginning
All the matter and energy in the universe existed within a single infinitesimal point – a gravitational singularity a billionth the size of a proton. Possibly due to a quantum fluctuation, inflation began.

10^{-43} SECONDS

2 Grand unification epoch
The universe was still tiny. At these incredible energy levels, the four fundamental forces were unified. Gravity soon separated to act independently, followed by electromagnetism.

10^{-32} TO 10^{-12} SECONDS

3 The quark epoch
As the universe began to expand, its 'supercooled' elementary particles formed as a 'hot soup' of ionised plasma. Matter particles interacted with the Higgs field, thus acquiring mass.

10 SECONDS

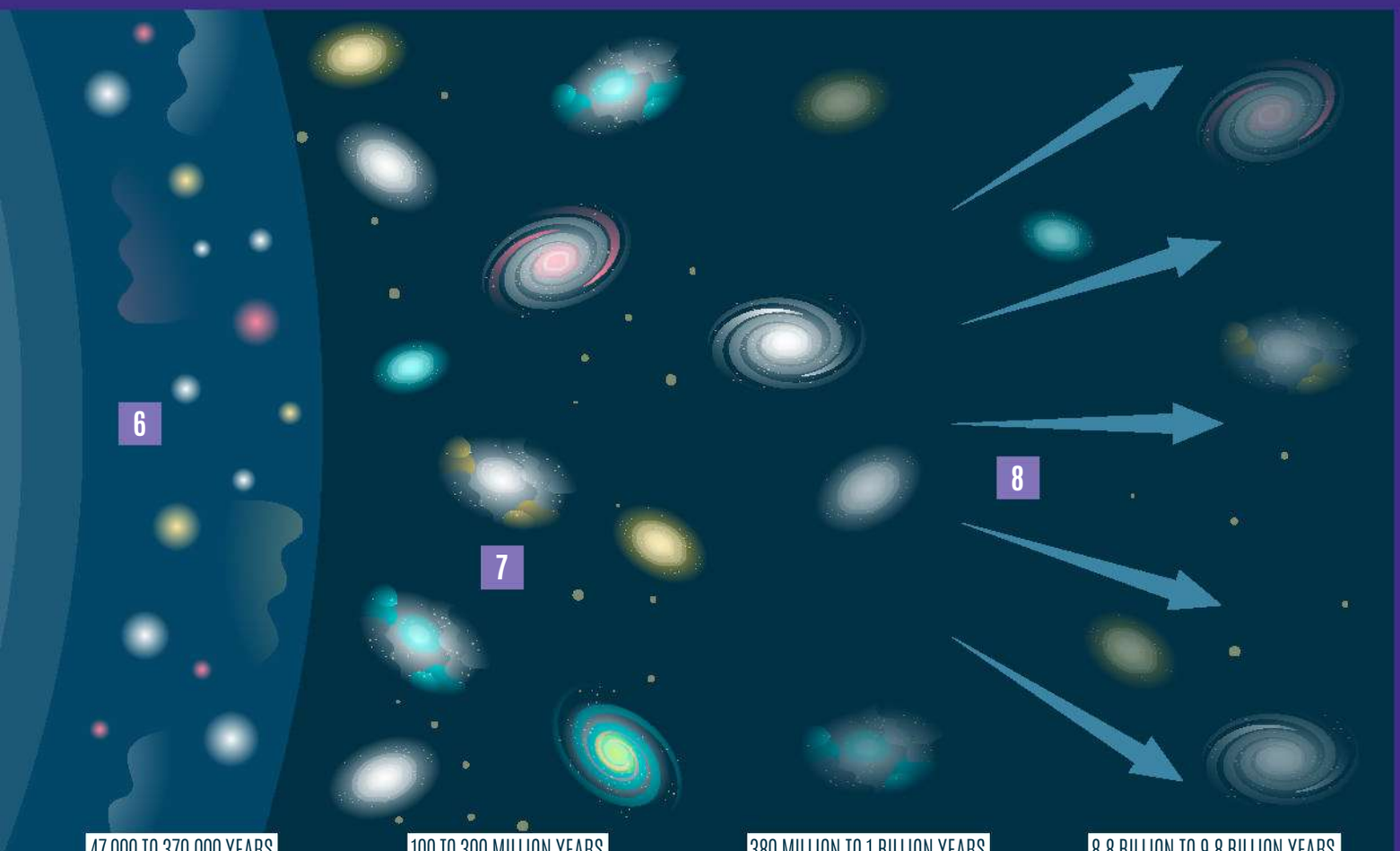
4 No more positrons
Positrons and electrons annihilated each other, with a small imbalance favouring electrons. These impeded the travelling of photons, meaning that the universe was opaque to light.

Supernovae such as SN 1994D helped scientists discover the acceleration of universal expansion

this, Einstein introduced the 'cosmological constant' – represented by the Greek letter lambda – to balance the effect of gravity and describe a static universe. History's most famous physicist scrapped it when he was convinced the universe was actually expanding, allegedly describing its introduction as his 'biggest blunder'.

Before that same century drew to a close, however, the expansion of the universe would deliver another shock to science. "In the late years of the past century, two cosmology groups determined that the expansion of the universe was speeding up, thus increasing the rate at which galaxies recede from the others," García explains. "It was proposed that there should be a form of matter-energy, not detected by our instruments to date, that produces a 'repulsive force' among galaxies at cosmic scales. Since this component is still elusive to our telescopes, it was named dark energy." This discovery has since been confirmed in a multitude of ways, including with observations of the cosmic microwave background (CMB), a radiation source that evenly permeates the entire universe and is left over from an event that occurred shortly after the Big Bang.

This discovery was shocking because if the universe began undergoing the rapid period of expansion that cosmologists call inflation just after the Big Bang, the attractive force of gravity should be slowing



47,000 TO 370,000 YEARS

5 The first light
The gravitational collapse of matter formed structure, and atoms began to form. As free electrons were snatched up, light was free to travel. The universe became transparent.

100 TO 300 MILLION YEARS

6 The first stars
Ordinary matter particles fell into structures created by dark matter. The stars began to take shape and the first stars began to shine. The oldest known star was formed at 200 million years.

380 MILLION TO 1 BILLION YEARS

7 Quasars and galaxies
The first quasars and galaxies formed. The oldest known galaxy with a supermassive black hole existed at 770 million years, hinting that black holes grew much earlier than this.

8.8 BILLION TO 9.8 BILLION YEARS

8 Dark energy dominates
Matter lost its dominance. The dark energy-dominated epoch began as it accelerated expansion. A new age of expansion began, but can researchers discover what drives it?

that expansion down. The fact that the expansion is speeding up means there must be some force acting against gravity. To explain this acceleration and account for energy arising from quantum fluctuations in 'empty space' that are inherent to the universe – known as 'vacuum energy' – giving rise to the effects of dark energy, modern cosmologists resurrected the cosmological constant and lambda.

Unfortunately, it's still a massive headache for cosmologists, with the observed value delivered by astronomy being hundreds of magnitudes smaller than the value predicted by quantum field theory. This has led to the cosmological constant being described as the worst theoretical prediction in the history of science. "The leading explanation for the cosmological constant is the vacuum energy contribution to the expansion of our universe," Lucas Lombriser, a professor at the University of Geneva who has been working on cosmic acceleration models for over a decade, says. "However, we do not understand why this contribution is neither very large nor exactly zero."

Lombriser speculates that the disparity in the value between observations of the cosmological constant and the universe's rate of expansion – and the theoretical figure derived from the contributions of the cosmos' particle content that emerges from quantum field theory – could possibly be rectified by a multi-source approach. "Multiple sources for dark energy would generally allow for more flexibility in the model that perhaps can explain current tensions that we observe between different cosmological measurements," he suggests, somewhat cautiously. "While a more complicated model with more ingredients allows more flexibility, it also involves more parameters. When selecting between different models as an explanation for our data, we usually opt for the simplest model that can explain the measurements."

García, albeit just as cautiously as Lombriser, puts forward another reason that a 'multi-source' approach to dark energy could help cosmologists understand the cosmological constant: "The main advantage

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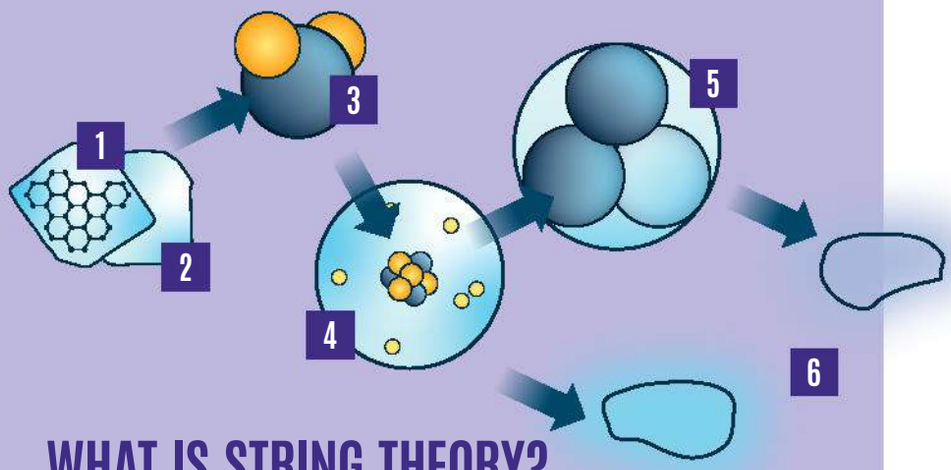


WHAT IS STRING THEORY?

1 String theory
String theory expands upon existing theories of matter, adding an extra fundamental level beyond that of fundamental particles.

2 Matter: the ice cube
The everyday matter we see around us is made up of molecules. In the example of the ice cube, it consists of molecules of H_2O.

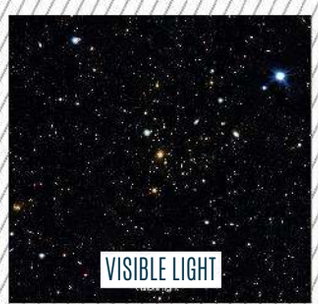
3 Molecules: H_2O
These molecules are composed of atoms bonded together. For water, this means one oxygen atom bonding to two hydrogen atoms.

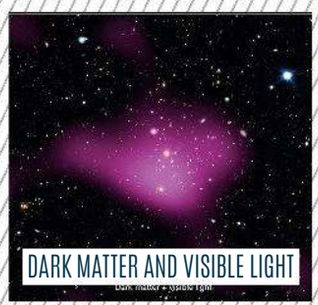
4 Electrons, protons and neutrons
Within these atoms is an internal structure made up of electrons with a negative charge orbiting a nucleus. This consists of nucleons: protons and neutrons.

5 Neutrons and protons: quarks
The nucleons are made up of 'flavours' of quarks. A neutron contains two down quarks and an up quark, while protons contain two ups and a down.

6 Beyond quarks
If string theory is correct, the fundamental particles – quarks and electrons – are made up of vibrating 'strings' that exist curled up within hidden spatial dimensions.

Surveys of galaxies could reveal dark matter clusters that help confirm multi-field dark energy theories





of this approach is that it allows us to explore a larger number of phenomena that could not be explained by a single model," she says. "For instance, an emerging early dark energy (EDE) model could be responsible for cosmic effects still unexplained by the cosmological constant. Then it could decay and deliver its energy density into the latter." García adds that one of the fundamental issues that persists with the cosmological constant in this EDE model is the failure to explain how that energy transfer occurs in the first place. "Exploring a multiple-source approach is relevant to solve these open questions in this theory."

Of course, the cosmological constant is only one dark energy suspect; another is a quantum field that permeates the entirety of space and evolves over time. Just as is the case with the cosmological constant, considering multiple sources for this contribution could solve a multitude of problems presented by such a model. Valeri Vardanyan is a cosmologist and theoretical physicist at the Kavli Institute of Physics and Mathematics of the Universe (IMPU) and the author of a recent study that puts forward the idea of multiple scalar fields acting as dark energy. "In our paper, we move away from such simple single-field models and put forward the idea that cosmic acceleration could be driven by the dynamics of multiple fields," he says.

One of the most interesting properties of the model Vardanyan and his colleagues suggest involves the rotation of these multiple scalar fields – something that isn't possible with a single field. "Due to such a rotational motion, several interesting features emerge," the cosmologist continues. "First of all, even though the scalar fields move fast as they rotate, the energy of such a system almost doesn't change over time." To imagine this, picture a bead placed in a bowl and how it would move as the bowl is kicked sideways. If the bowl spins fast enough, the bead stays at a constant height within it. It's the same for the rotation of the scalar fields and their energy levels.

Ultimately, Vardanyan believes that this behaviour means a multiple-field system that 'looks' just like a cosmological constant, despite having very rapid internal dynamics. This could also potentially protect the idea from future findings. "Imagine a situation in the future in which more precise cosmological observations detect no time variation of dark energy," Vardanyan muses. "This would mean the 'death' of scalar-field dark energy ideas, but not for ideas of multiple fields with this turning motion."

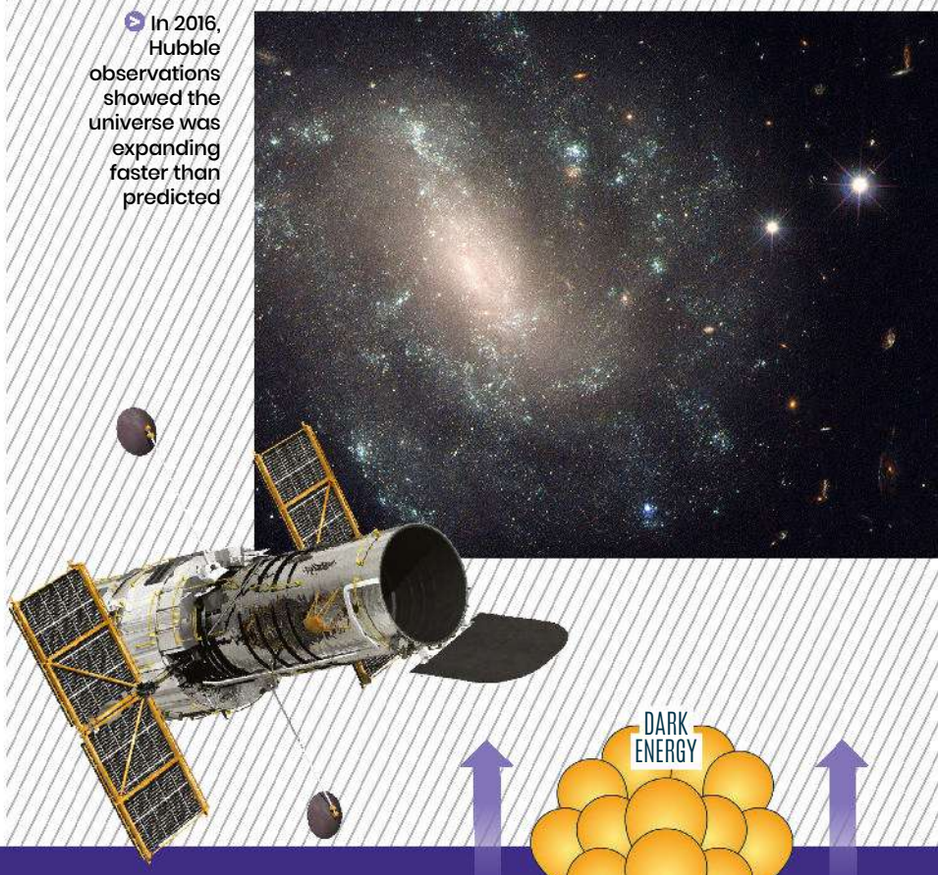
The motion of multiple fields also helps alleviate technical problems associated with explaining dark energy with the use of quantum fields – particularly the difficulty physicists have had in uniting a single universal quantum field with string theory. "Our approach is 'bottom-up' – we didn't start from a fundamental theory, such as string theory, but rather proposed a model that describes a low-energy universe," he says. "Constructing realistic models of cosmic acceleration in the scope of string theory is considered to be a very hard problem, but multiple scalar fields are ubiquitous in string theory constructions. Our model is inspired by string theory, though not directly related to it."

Despite behaving just like the cosmological constant, Vardanyan points out that this multiple-field system possesses a feature that could allow it to be distinguished from its fellow dark energy candidate by future observations. Doing this requires the study of another element of the mysterious 'dark universe': dark matter. "Detailed calculations show that such a turning behaviour leads to enhanced fluctuations in the dark matter sector, which would additionally lead galaxies in the universe to be more clustered."

While considering multiple sources for the origin of dark energy could clean up some problems with both the cosmological constant and a quantum field explanation,

doing so may seem a little arbitrary. Both García and Lombriser point to Occam's razor – a loose scientific rule that suggests explanations should require as few additional mechanisms as possible – as a hindrance to the speculation of multiple dark energy sources. For Vardanyan, however, the complexity of the natural world provides a convincing argument to at least consider multiple sources for dark energy. "The physics governing our visible world – the Standard Model of particle physics – is very complex, with a multitude of ingredients and interplays between these ingredients. Yet the visible world is only a tiny fraction of the energy budget of the universe," Vardanyan concludes. "It's hard to believe, at least for me, that the universe needs such complexity for describing the visible world, while a simple cosmological constant, or even a slightly more complicated single scalar field, is all there is in the dark energy sector. There should be more complexity out there, and multi-field dark energy is taking us one small step closer to understanding that complexity."

Robert Lea
Space science writer
Rob is a science writer with a degree in physics and astronomy. He specialises in physics, astronomy, astrophysics and quantum physics.



In 2016, Hubble observations showed the universe was expanding faster than predicted

HOW DARK ENERGY BEHAVES

1 Cosmic tug of war
In many ways, dark energy can be considered the counterpart of gravity. Gravity's influence draws matter in the galaxy together, but dark energy works to push it apart.

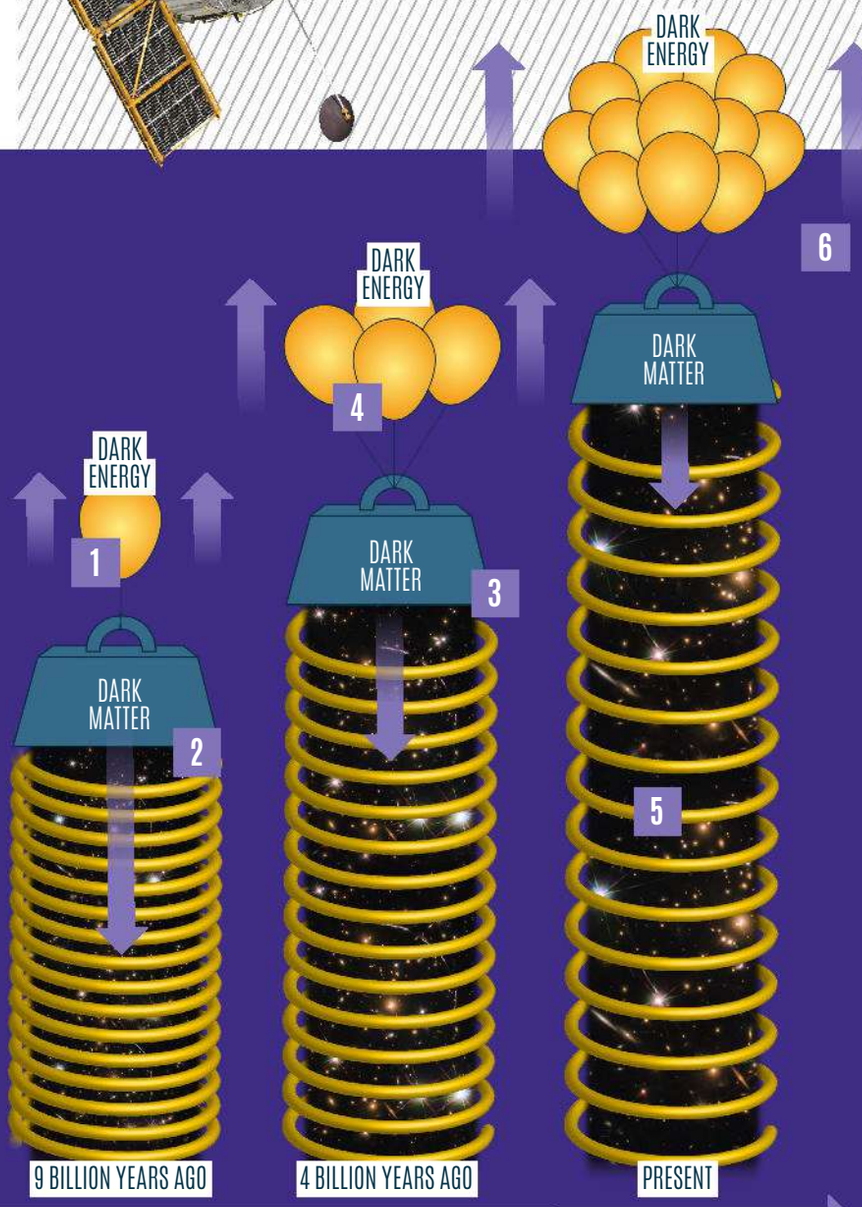
2 Holding it together
Astronomers calculated that the gravitational influence of visible matter alone wasn't enough to hold galaxies together, even before accounting for dark energy.

3 Dark matter boosts gravity
There's an unseen form of matter exerting its influence. Dark matter accounts for about 85 per cent of the matter in the universe.

4 The dark universe at war
As dark matter outweighs ordinary matter, it's dark matter's gravitational influence that dark energy is working against.

5 The space between us
Dark energy seems to expand the very space between galaxies rather than the galaxies themselves.

6 Where will it all end?
The universe could succumb to either one of these influences, stretching out to an inevitable 'heat death' or snapping back and contracting in a 'Big Crunch' scenario.



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INSTANT EXPERT

DOES THE SUN STAY STILL IN THE SOLAR SYSTEM?

We tend to think of our star as the stationary centre of our system, but the planets do make it wobble

Exoplanet hunting has been dominated by NASA's Kepler and Transiting Exoplanet Survey Satellite, which stare out at the stars looking for drops in brightness as the members of other planetary systems pass between ourselves and their parent stars. But the first exoplanets were discovered by the 'wobble' method, which looks for changes in starlight as the star is slowly dragged around by its accompanying planets. The difference is small, as stars are generally much larger than their collection of planets, and for multi-planet systems the motion is a combination of the influence of all partners.

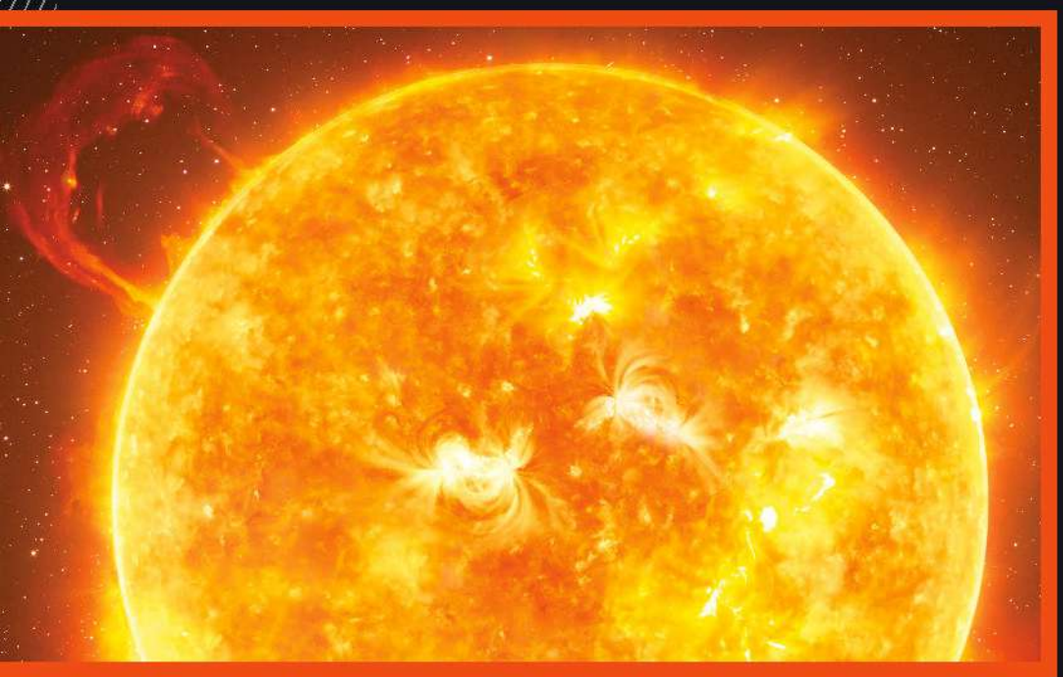
All the bodies involved in an orbital relationship will be influenced by each other to some degree; it's easiest to envisage the most extreme case, two equally sized objects orbiting each other. If Earth and the Moon were the same size, they would orbit each other around a point halfway between them – this is called the 'barycentre', the centre of mass of the whole system. As one body gets larger the barycentre moves closer to it, with the smaller body following a larger circle and the heavier body a smaller one. In reality, Earth is four times the size of the Moon, so the barycentre is 4,670 kilometres (2,902 miles) from Earth's centre, or 1,710 kilometres (1,063 miles) underground. However, in the case of Pluto and Charon, they are so closely matched that their barycentre is 960 kilometres (597 miles) above Pluto's surface.

BIO
ROBIN HAGUE
Robin is a science writer, focusing on space and physics. He is the current head of launch at Skyrora, coordinating launch opportunities for Skyrora's vehicles and liaising with UK launch regulators.

"All the bodies involved in an orbital relationship will be influenced by each other to some degree"

So two bodies follow simple circular paths around the barycentre, but the Solar System has at least nine major bodies, depending upon definitions, and all those influences add up. By far the biggest solar wobble is created by Jupiter; it's 2.5 times the mass of all the other planets combined and endeavours to pull the Sun around in one large wobble, centred 46,000 kilometres (28,583 miles) above the nominal solar surface every 11 years. But then Saturn has a mass 30 per cent that of Jupiter and an orbit of 29.5 years, so its wobble is superimposed on Jupiter's, leading to a loop-in-a-circle-shaped path that progressively changes as the planets move positions. Uranus and Neptune are also big enough to introduce wobbles that are significant on the scale of the Sun's radius, and then all the terrestrial and dwarf planets and their moons add their own small wobbles on top.

Ultimately, the Sun dances around a combined path of loops as the planets shift, such that the barycentre of the whole Solar System is sometimes within the solar sphere and sometimes outside. If there should be an alien civilisation out in one of the many systems we now know about, they would be able to tell from analysing the motion of our Sun – as perhaps we have already done with theirs – that there are eight or more planets in its possession.



The Sun is also moving through the galaxy, orbiting the Milky Way's centre

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Centre of the Solar System
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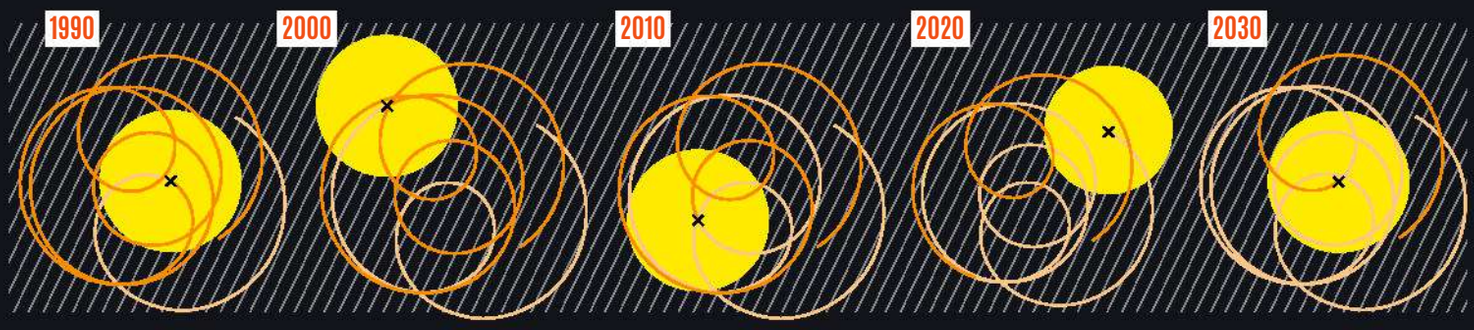
1990
2000
2010
2020
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© Getty

This sky map from Gaia is based on measurements of nearly 1.7 billion stars, showing off the galactic plane, interstellar dust and neighbouring galaxies

USER MANUAL

GAIA

For nine years, this Milky Way mapper has pinpointed over a billion stars to create an expansive dataset

THE SPECS

Launch: 19 December 2013

Rocket: Soyuz ST-B/ Fregat-MT

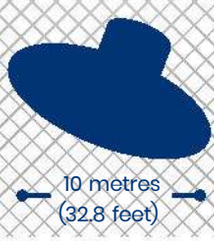
Target: Earth-Sun Lagrangian point 2

Operator: European Space Agency

Estimated cost: £650 million ($860 million)

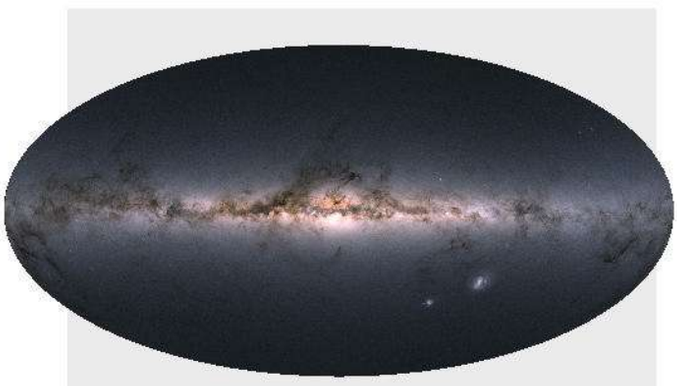
Time in space: Nine years

Distance from Earth: 1.5 million kilometres (932,057 miles)



This almost sombrero-shaped spacecraft has been mapping the stars of our galaxy for nine years. Its first data release contained unrivalled information on nearly 1.7 billion stars, and is to date the greatest catalogue of stars ever produced. The European Space Agency (ESA) initially had the idea of using Gaia as an optical interferometer mission – meaning that Gaia originally would have been a series of smaller telescopes working together to create an image similar to that of a larger telescope – thus the ESA gave the mission its original name: the Global Astrometric Interferometer for Astrophysics, or GAIA. After the mission evolved and the interferometer idea was dropped, the name stuck. However, the previous design was altered and Gaia's primary objective would be to create the largest, most precise three-dimensional map of the stars in our galaxy within its intended five-year mission, building on the legacy of the Hipparcos mission.

The name wasn't the only aspect that changed. Launch was originally scheduled for December 2011. After a series of complications to Gaia and the liftoff schedule, the spacecraft finally left Earth two years behind schedule, riding aboard a Soyuz-Fregat rocket. With a launch mass of 2,030 kilograms, Gaia was sent on its way to its new home at Lagrange point 2 (L2) roughly 1.5 million kilometres (932,057 miles) away from Earth. This is an ideal location to observe the wider universe, and is a cosmic 'parking spot' which relies on the gravity of the Sun and Earth to keep the space observatory fixed in this one spot. While at L2, Gaia is in a Lissajous-type orbit that has a period of about 180 days around a fixed point at L2.



ANATOMY OF GAIA

The ESA spacecraft is fitted with the finest equipment, intended to detect any speck of light coming from any section of the sky

1 Thermal tent
This thermal tent covers the payload module and protects it from being exposed to extraneous radiative thermal inputs.

2 Payload module
This module accommodates the two telescopes and electronics in order to manage and process the raw data collected.

3 Service Module
This contains equipment to maintain basic control, providing power, storing data and processing video data.

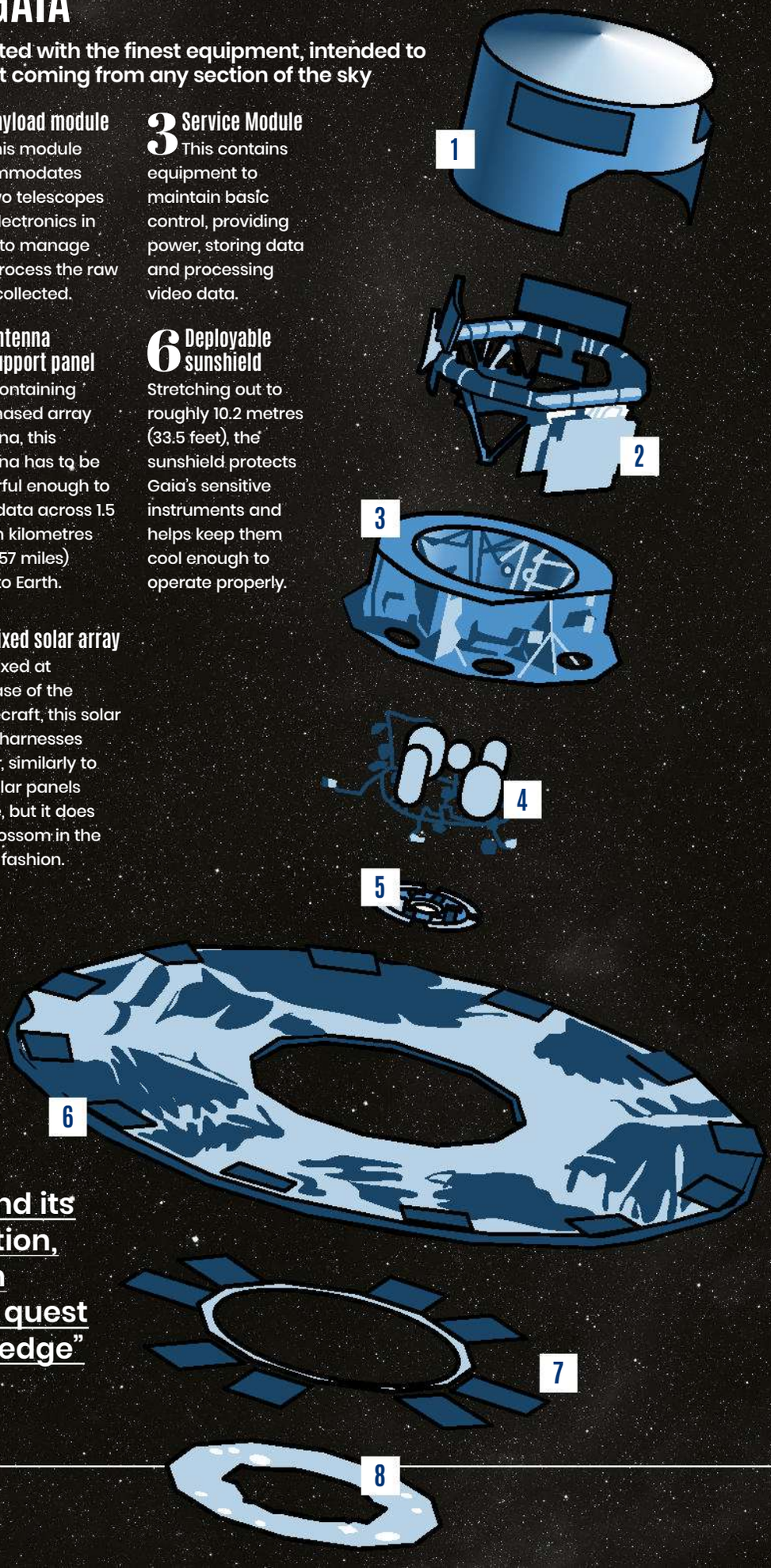
4 Propellant tanks
At launch there was 400 kilograms of propellant in order to navigate the spacecraft to L2, keep it in orbit and orientate its main instruments away from the Sun's light.

5 Antenna support panel
Also containing the phased array antenna, this antenna has to be powerful enough to send data across 1.5 million kilometres (932,057 miles) back to Earth.

6 Deployable sunshield
Stretching out to roughly 10.2 metres (33.5 feet), the sunshield protects Gaia's sensitive instruments and helps keep them cool enough to operate properly.

7 Solar panels
There are eight solar panels attached to the outside of the deployable sunshield. These collect the Sun's light and harness it for energy to power the spacecraft.

8 Fixed solar array
Fixed at the base of the spacecraft, this solar array harnesses power, similarly to the solar panels above, but it does not blossom in the same fashion.



"Extended beyond its five-year operation, Gaia has proven successful in its quest for stellar knowledge"

©ESA; Adrian Mann

HOW TO CREATE A 3D MAP OF THE STARS

1 The dynamic duo at work

The two telescopes get to work in scanning the skies, observing each of the billion stars 70 times over the five-year mission.

2 First scan of the focal plane

The stars' light is first focused on the main instrument, the astrometric field, which calculates the stars' position, proper motion and distance.

3 Red and blue photometers

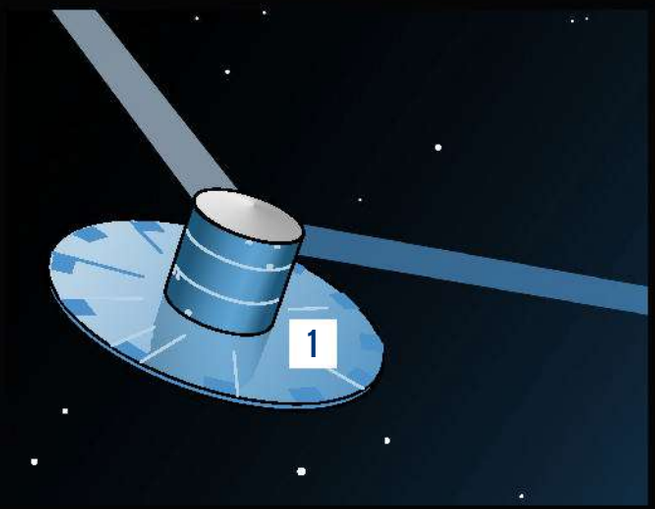
These gather spectral information, giving astronomers information about stars' temperature, mass and chemical composition.

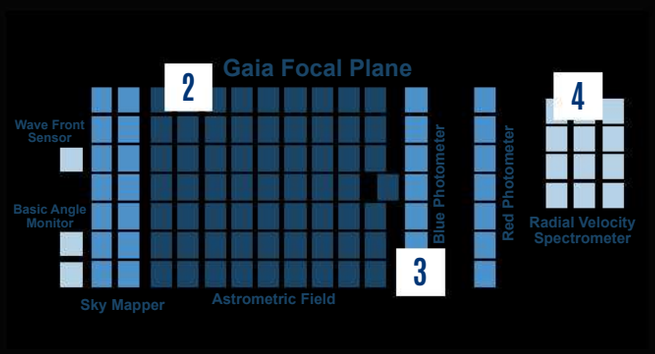
4 Radial velocity

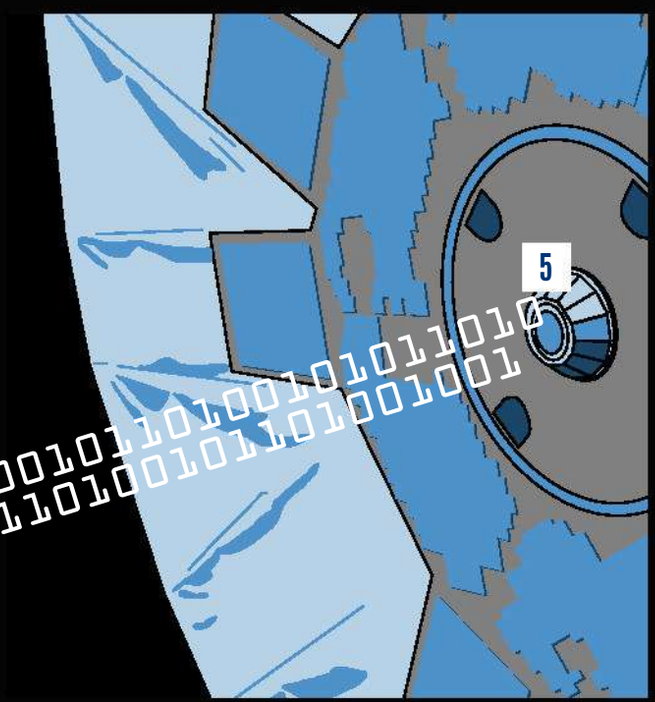
Data is collected about each star's radial velocity relative to Gaia, allowing for accurate descriptions of a star's movement.

5 Beamed back to Earth

All this data is stored within Gaia and sent back to Earth from L2. This data is then processed by a number of astronomers, and an accurate 3D map can be produced.







Before Gaia could examine the sky properly there were some hiccups. The Gaia team needed to sort out issues with the optics, including some areas of water freezing and 'stray light', where some of the Sun's light was making its way into Gaia's focal plane. On 25 July 2014, Gaia officially began its science mission and could start scanning the sky. On average, Gaia observed each single star, of the intended billion stars, 70 times over the course of its initial five years. Sweeping the skies once every six hours, the two onboard telescopes focus the light that is measured by three major instruments fixed on the same focal plane. The focal plane can be thought of as one of the largest space cameras ever created, consisting of 106 charge-coupled devices and equating to an enormous 1 billion pixels. The first instrument, the astrometric instrument, is devoted to measuring a star's position, proper motion and parallax – therefore its distance. The second, the photometric instrument, consists of a blue and a red photometer; they provide information about a star's temperature, mass and chemical composition. Lastly, the third instrument, which is the Radial-Velocity Spectrometer, measures how fast a subset of stars are moving relative to Gaia.

Extended beyond its original five-year operation, Gaia has proven successful in

VITAL STATISTICS

10.2 METRES — About one-fifth as tall as the Statue of Liberty

1.5 MILLION KILOMETRES — Roughly 37 Earth orbits

2,030kg LAUNCH MASS — Roughly the weight of two cows

70 BILLION IMAGES — Over 1 billion observations each month

1 BILLION STARS — Roughly one per cent of the stars in the Milky Way

HEAD TO HEAD
GAIA VS HUBBLE

With regards to physical dimensions, Hubble towers above Gaia. With Hubble being 13.2 metres by 4.2 metres (43.3 feet by 13.8 feet), the famous space telescope is about three times as long and almost twice as wide as the ESA's star-mapping space observatory. In terms of launch mass, Hubble also reins supreme, as it was 8,856 kilograms heavier.

Gaia does have a much larger collective focal plane though, as Hubble is made up of different cameras, the two main ones being the Advanced Camera for Surveys (ACS) and the Wide Field Camera 3 (WFC3). Each of these has 16 million pixels, compared to Gaia's 1 billion pixels.

Hubble
12,247
kilograms

Gaia
1,392
kilograms

its quest for stellar knowledge. This is shown in its three major data releases, the first of which came out on 14 September 2016 and the second on 25 April 2018. The third was split into two parts, released on 3 December 2020 and 13 June 2022. The first release detailed the precise position and brightness of over 1.1 billion stars, which at the time was the most detailed 3D map ever created.

After a period of 22 months of data collection, a second catalogue was released, and scientists marvelled at the results: the position and brightness of 1,692,919,135 stars was found. For some of the brightest stars in this survey, the level of precision was so good that it would be akin to an observer on Earth being able to locate a coin lying on the surface of the Moon, which on average is about 384,000 kilometres (239,000 miles) away.

The image of the night sky created by Gaia's second data release is breathtaking. The mixture of light stretching across the plane of the Milky Way, blocked in many places by intergalactic dust and two of our satellite galaxies, the Small and Large Magellanic Clouds, is a real thing of beauty. To think that each dot of light is a star that has been watched for many years is extremely humbling and inspiring.

The datasets that Gaia has produced as part of this amazing project are certainly keeping scientists busy. The data collected also includes information on more than 550,000 variable stars, which are stars that change in brightness over time; velocities for over 7.2 million stars; the surface temperatures for over 160 million stars and also data on Solar System objects. Although Gaia was originally planned to be a five-year mission, ending operations in mid-2019, the ESA approved an extension until the end of 2020, but Gaia is still hard at work to this day. A final catalogue based on data from the initial five-year mission was produced in 2022.

TOP TECH

GAIA'S DIGITAL DETECTORS: THE BILLION-PIXEL CAMERA

Gaia contains one of the largest cameras to ever leave Earth, consisting of 106 CCDs that make up almost a billion pixels. Compared to the iPhone 8's 12-million-pixel camera, Gaia's camera is over 80 times more impressive. These CCDs are split up into subsections that make up the three main instruments: the astrometry field, the photometric instrument and the radial velocity spectrometer, including some minor instruments that track the motion of stars and realign the telescope. Working together, these CCDs are what make Gaia a success.

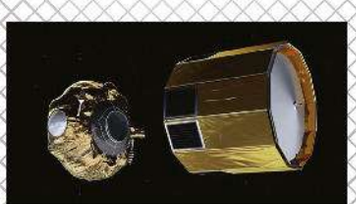
HOW TO...

LAUNCH TO A LAGRANGE POINT

1 Achieving liftoff
In order to launch a space observatory, a powerful rocket is needed in order to produce enough thrust to escape the Earth's gravity.

2 In low-Earth orbit
Fregat-Gaia separated from Soyuz into a low-Earth parking orbit. The rockets then launched the spacecraft towards L2 after one orbit of the Earth.

3 Next stop L2
Fregat sent Gaia into a hyperbolic L2 transfer trajectory. After a second Fregat burn, the space observatory detached and Fregat was sent elsewhere.



4 Orbital insertion
It took about three weeks to reach Lagrange point 2. In approach to L2, the sunshields and solar arrays were deployed and communications made.

© ESA/ - Adrian Mann

FOCUS ON

A LOPSIDED STAR CLUSTER MAY DISPROVE NEWTON AND EINSTEIN'S THEORIES

An uneven distribution of stars in several nearby clusters may offer evidence of MOND – a controversial theory of gravity that rejects the existence of dark matter

Reported by Tom Metcalfe

Astronomers observing star clusters in our galaxy have found evidence that challenges Newton's laws of gravity and could upend our understanding of the universe. The finding could support a controversial idea that does away with dark matter. Researchers found this evidence by observing open star clusters, loosely bound groups of up to a few hundred stars sitting within larger galaxies. Open star clusters have trails of stars, known as 'tidal tails', in front of and behind them.

The researchers' observations indicate that such clusters have many more stars sitting in the overall direction of their travel through space than trailing behind. This throws into question Isaac Newton's law of universal gravitation, which suggests that there should be the same number of stars in both tidal tails. "It's extremely significant," said astrophysicist Pavel Kroupa of the University of Bonn. "There is a huge effect." Kroupa is the lead author of a study that argues the observations are evidence of modified Newtonian dynamics (MOND) – an alternative theory of gravity to Newton's widely accepted universal law of gravitation.

This uneven distribution of stars is noticeable, but not extreme enough for any sort of dark matter – an invisible substance thought to exert a powerful gravitational pull on the universe's visible matter – to be involved. "This is a game changer," he said.

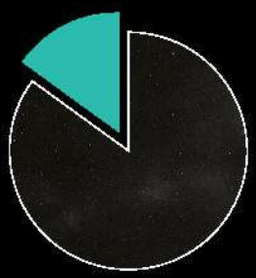
Isaac Newton's universal law of gravitation, published in 1687, states that every particle in the universe attracts every other with a force proportional to their masses and inversely proportional to the square of their distance. Albert Einstein later incorporated this law into his theory of general relativity, which was published in 1915. But Kroupa said that at the time of both Newton and Einstein, astronomers didn't know that galaxies even existed, so MOND was developed to bring it up to date with observations.

MOND, developed in the early 1980s, argues that regular Newtonian dynamics don't apply on the very large scales of galaxies and galactic clusters, although most astrophysicists think they do. The main consequence of MOND is that dark matter doesn't exist – an idea that most astrophysicists dismiss, Kroupa said. "The majority of scientists completely reject MOND," he said. "Many serious scientists don't think MOND is serious, and so they wouldn't consider looking at it."

In their study, the authors report observations of five of the closest open stellar clusters to Earth, including the Hyades – a roughly spherical group of hundreds of stars that is only about 150 light years from our Sun. The researchers observed that stars had accumulated in the leading tidal tail in all five of the clusters, while the greatest discrepancy from regular Newtonian dynamics was seen in the Hyades Cluster, where there are better measurements, Kroupa said.

The observed discrepancies strengthen the case for MOND, but they can't be a result of the invisible action of dark matter. In the case of the Hyades, "we would have to have a clump of dark matter there of 10 million solar masses" to explain the results, Kroupa said. "But it's just not in the data."

WHAT IS DARK MATTER?

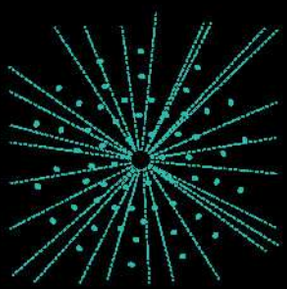


We have no idea, despite it making up 85 per cent of the stuff in the universe.

There's six times the amount of dark matter as all the planets, stars, gas clouds and galaxies in the universe added together.

We don't know what it is or what it is made of.

The favourite theory is a hypothetical weakly interacting particle beyond the Standard Model of particle physics, similar to neutrinos but heavier.



It provides the extra gravitational attraction that keeps galaxies, galaxy clusters and the universe from flying apart.

Every galaxy is surrounded by a halo of dark matter.

Whatever it's made of, we need it and use it to explain the structure of galaxies, clusters of galaxies and even the universe as a whole.

The term 'dark matter' was introduced in the 1930s to refer to missing normal gaseous matter hidden from view.

TIMELINE

1930s

1940 – 'Dark matter' was coined to describe the missing matter in galaxy clusters.

1950 – Measurements of the spin of gas within individual galaxies' outer discs needed the same missing mass to make any sense.

1960 – Vera Rubin and Kent Ford surveyed hundreds of galaxies and found all were surrounded by dark matter.

1970

1980 – Cosmologists were using it to explain the structure of the universe itself.

1990 – It was clear you needed this missing mass everywhere in the universe.

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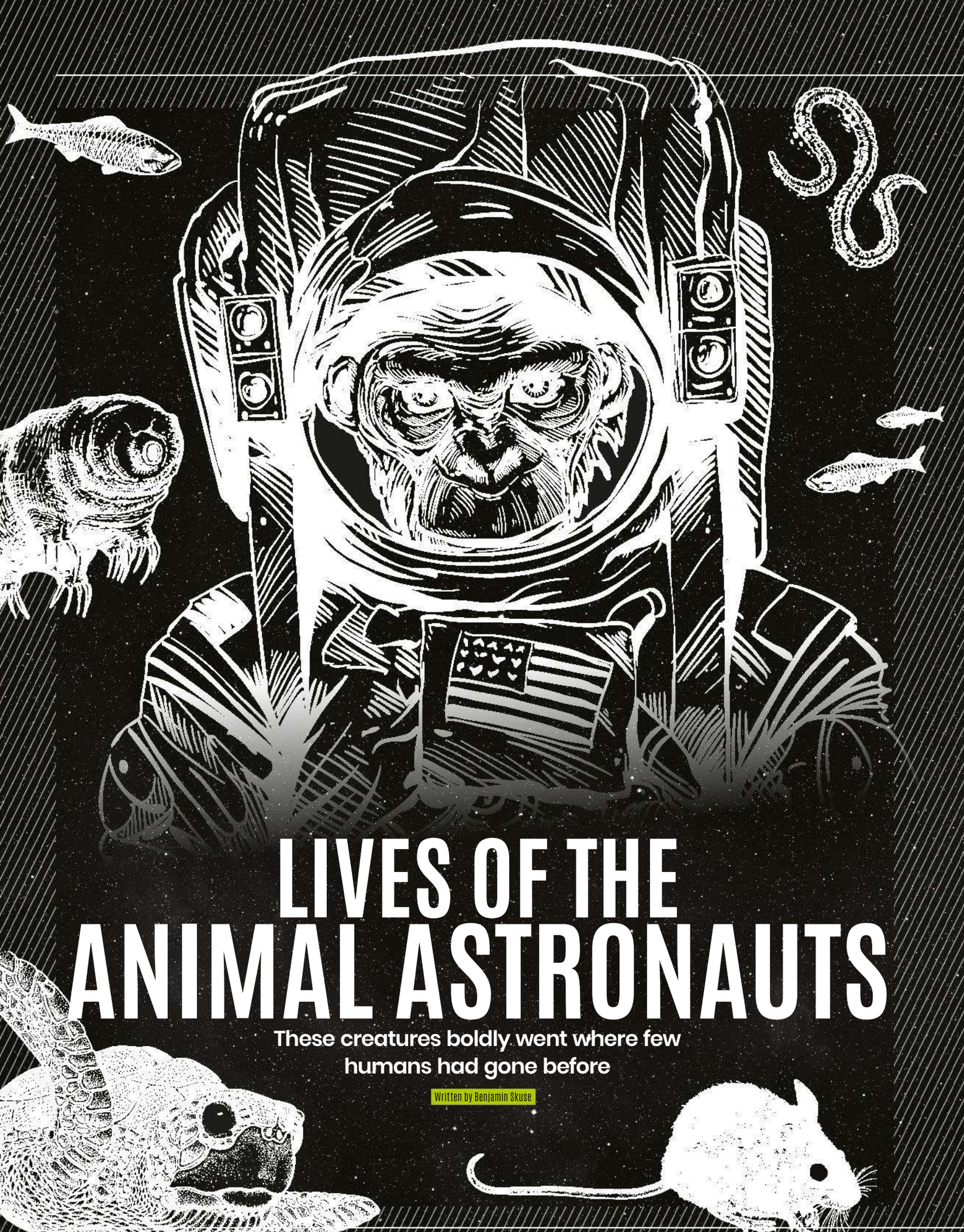


LIVES OF THE ANIMAL ASTRONAUTS

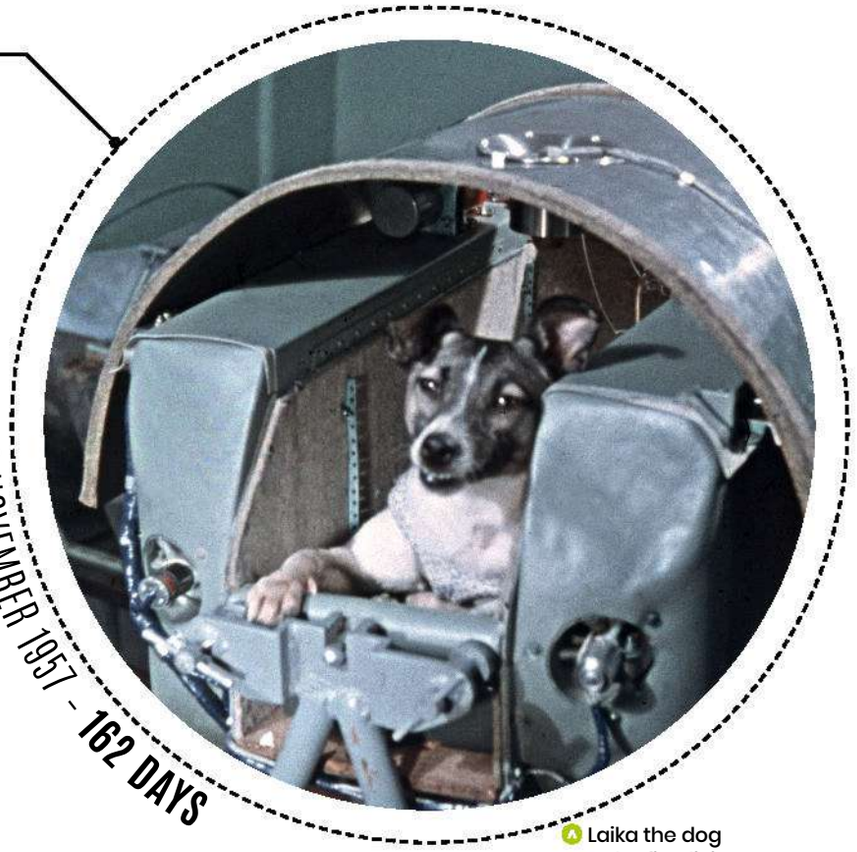
These creatures boldly went where few humans had gone before

Written by Benjamin Skuse

MUTTNIK ORBITS EARTH

PERISHED

In the mid-20th century, the USSR launched dozens of hardy stray dogs above Earth's atmosphere to test whether humans could handle the rigours of space. The most famous is Laika – the first living creature to go into orbit. Captured wandering the streets of Moscow, Laika – which means 'barker' in Russian – was strapped into a tiny space module and launched aboard Sputnik 2. Though Soviet scientists never intended Laika to return to Earth alive, at the time they suggested she had survived in space for four days to a week before dying peacefully. It was revealed in 2002 that her demise had been rather more harrowing. Laika died from overheating and panic no more than seven hours after the mission began because a fan had failed. Her capsule orbited Earth 2,570 times before burning up in the atmosphere five months after blast off. In August 1960 a canine pair named Belka and Strelka – joined by a rabbit, 42 mice and two rats – were strapped into Sputnik 5, launching into space and safely returning. Eight months later, Yuri Gagarin famously followed in their pawsteps. Strelka went on to have six puppies, one of which, Pushinka, was given to US president John F. Kennedy in 1961 by Soviet premier Nikita Khrushchev. Pushinka had four puppies with one of Kennedy's dogs, which the president affectionately referred to as pupniks.

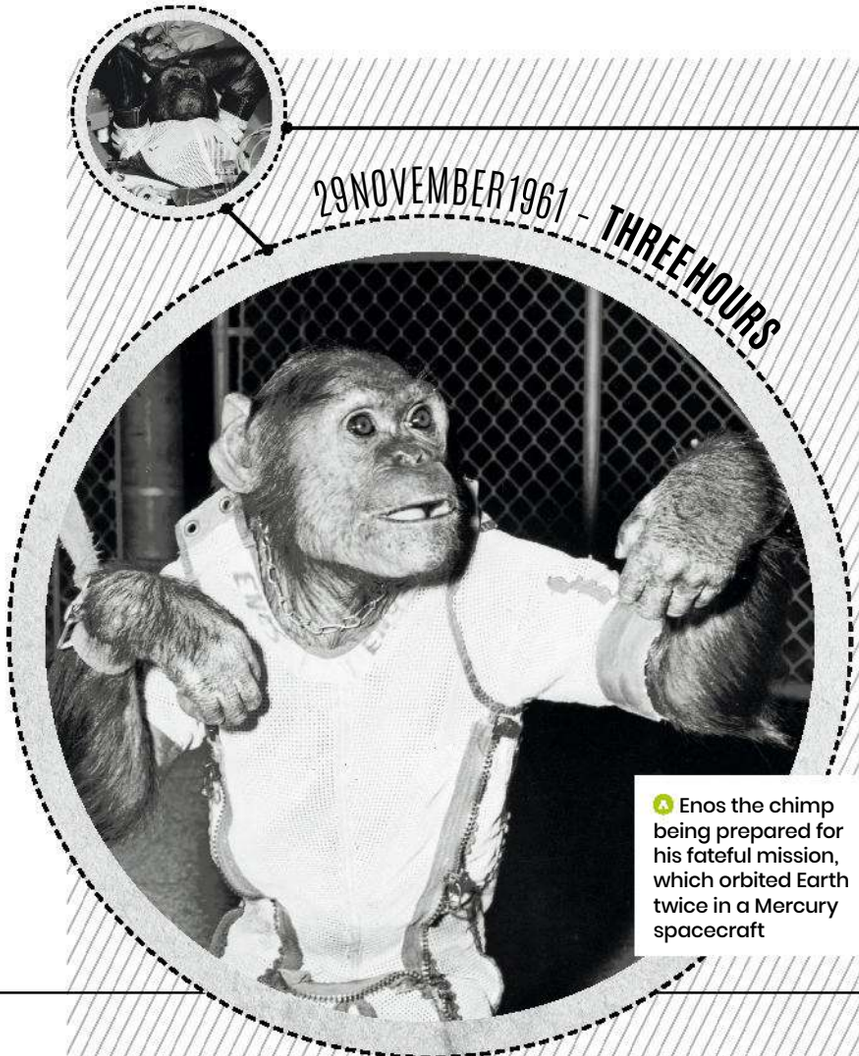


Laika the dog was the first living creature to orbit the Earth

ENOS' AGONISING SPACEFLIGHT

SURVIVED

Enos wasn't the first primate in space – that accolade went to Ham earlier in 1961. His spaceflight was intended to test equipment and procedures before risking a NASA astronaut. Enos' 1,263 hours of training for the flight included 'avoidance conditioning', during which electric shocks were administered to the soles of his feet if he responded incorrectly to tasks. This training aimed to get Enos to pull one of three levers in order to pick the odd one out of three presented shapes. In space, Enos began well during his first battery of tests. However, at the start of the second, the central lever malfunctioned. As a result, Enos was subjected to 76 unwarranted shocks. During the second orbit of an intended three, the flight encountered further problems. Alongside faulty equipment, a stuck thruster was haemorrhaging fuel. This prompted NASA to terminate the flight early. The stuck thruster caused the capsule to touch down hundreds of miles from where it should have. This meant Enos was stuck inside for 3 hours and 20 minutes. By the time he was extracted, Enos had broken through the protective belly panel, stripped off most of his physiological sensors and had forcibly removed his catheter while the balloon was still inflated. A little less than a year later, Enos died of dysentery – a sad end to an unlucky space chimp.

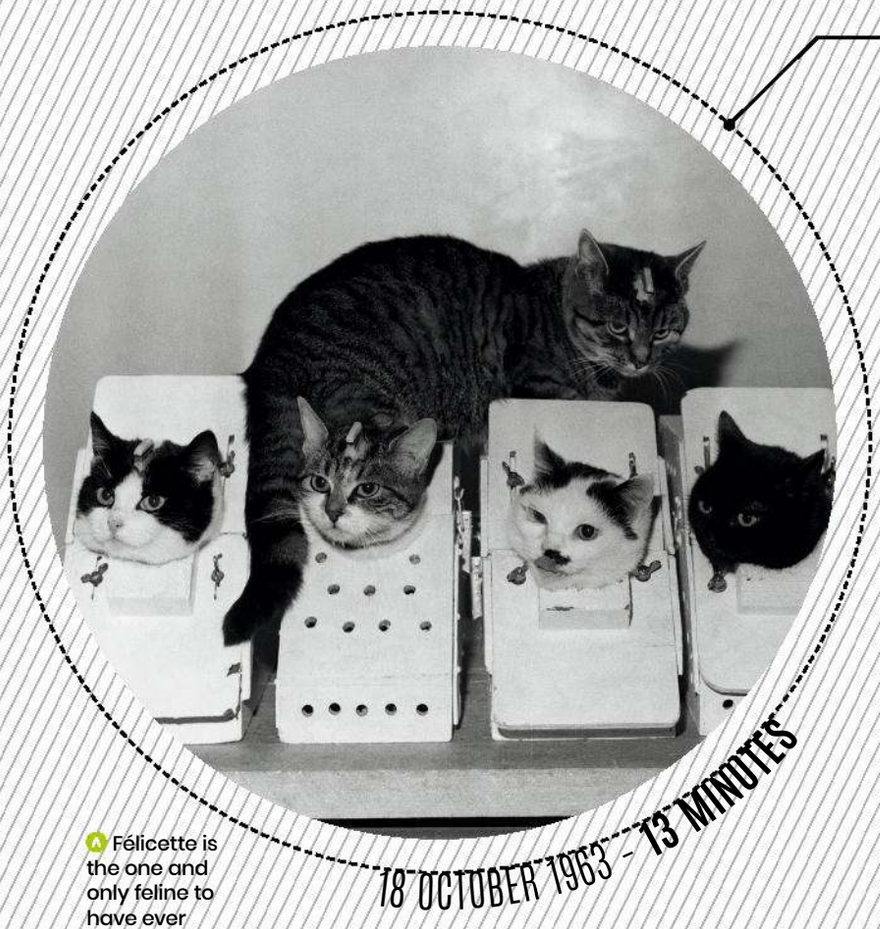


Enos the chimp being prepared for his fateful mission, which orbited Earth twice in a Mercury spacecraft

THE ONE-AND-ONLY SPACE CAT

SURVIVED

A stray cat plucked from the streets of Paris became the first and only feline sent into space. The French had previously launched three rats into space and wanted to upgrade to larger mammals to study how they responded to weightlessness. To this end, researchers captured 14 cats to train for the journey into space. These would-be feline astronauts were subjected to surgery to implant electrodes in their brains and testing which included compression chambers and centrifuges. In the end, Félicette – a petite tuxedo cat – was chosen for the mission. She wasn't a late replacement for a male cat called Felix who had escaped, as has been widely misreported. Aboard a Véronique AGI sounding rocket launched from a base in the Sahara Desert, she flew 157 kilometres (97.5 miles) above Earth and spent several minutes in zero gravity, all while scientists monitored her progress via the electrodes implanted in her brain. Félicette survived her trip to space and her return to Earth. Sadly, after living for two to three months back on Earth, she was put down so her brain could be studied. A second and final feline was launched towards space less than two weeks later, but that rocket failed on takeoff, leading to the loss of its furry crew member. Thanks to a Kickstarter campaign raising about £43,000 ($52,000), Félicette was commemorated when a bronze statue honouring the one-and-only space cat was unveiled at the International Space University in Strasbourg, France.



18 OCTOBER 1963 - 13 MINUTES

Félicette is the one and only feline to have ever successfully ventured into space

"A stray cat from the streets of Paris became the first and only feline sent into space"

14 SEPTEMBER 1968 - 6.5 DAYS

SLOW AND STEADY WINS THE RACE

SURVIVED

Bringing new meaning to Aesop's fable of *The Tortoise and the Hare*, in the race to the Moon between the US and USSR, it was two steppe tortoises who pipped the Apollo 8 crew in being the first vertebrates to successfully journey around the Moon. Launching from a modified Soyuz capsule, the unnamed tortoises – joined by mealworms, wine flies, plants, seeds, bacteria and other life, plus a 70-kilogram mannequin containing radiation detectors in the pilot's seat – were sent on a circumlunar trajectory, looping around the Moon but not orbiting it. During this time, the Zond 5 spacecraft reached a closest distance of 1,950 kilometres (1,212 miles) from the Moon and took high-quality photographs of Earth at a distance of 90,000 kilometres (55,920 miles). All occupants survived their trip, splashing down in the Indian Ocean on 21 September. Upon assessment back on land, Soviet scientists reported that the tortoises had lost ten per cent of their body weight, but otherwise seemed to be in good health, remaining active and showing no loss of appetite.

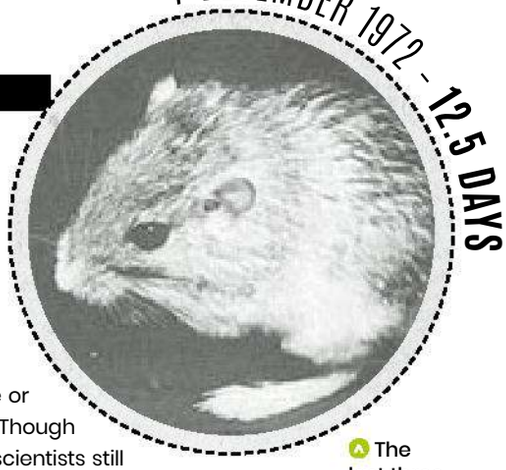
Two tortoises beat the Apollo 8 crew in being the first vertebrates to reach the Moon

THE LAST LUNAR VENTURERS

FOUR SURVIVED, ONE PERISHED

Even at the time, Apollo 17 was a poignant mission, concluding the Apollo program and signalling an end to human travel to the Moon. Yet the smallest occupants on the mission offered hope that humanity would soon be venturing even further afield, to Mars. They had been implanted with radiation monitors under their scalps to study the effects of cosmic rays during long space travel. One of the animals died during the mission for unknown reasons, but the other four remained alive, circling around the Moon a record of 75 times in 147 hours and 43 minutes with astronaut Ron Evans, while Eugene Cernan and Harrison Schmitt were conducting the last moonwalks below. After returning to Earth, the four remaining mice were killed and dissected. Although lesions in the scalp and liver were detected, they appeared to be unrelated to one another and were not thought to be the result of cosmic rays. Furthermore, no significant damage was found to the brains, retinae or other organs. Though inconclusive, scientists still learned a valuable lesson from the rodent experiment – that cosmic-ray experiments in particle accelerators on Earth could be useful as they offered similar results to much more difficult space experiments. As a result, significant progress in radiobiology has been made in recent decades towards understanding the effects of cosmic rays on humans for future Mars missions.

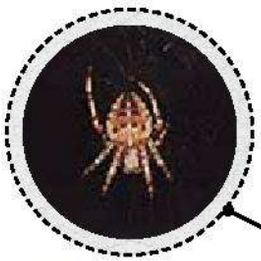
7 DECEMBER 1972 - 12.5 DAYS

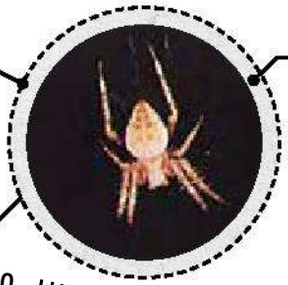


The last three humans to visit the Moon were joined by five pocket mice held in tiny tubes

WEAVING A WEB OF KNOWLEDGE

BOTH PERISHED





A student conceived the experiment that saw two orb-weaving spiders being sent to SkyLab

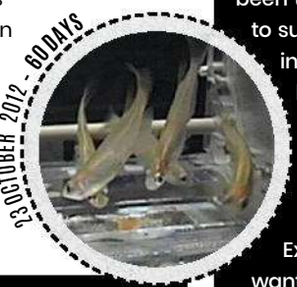
28 JULY 1973 - 59 DAYS

High-school student Judith Miles was the spark that led to the first spidernauts lifting off from Earth. She proposed an experiment to NASA called 'Web Formation in Zero Gravity' in which spiders would be released into a box where cameras would record their actions to assess how well they adapted to the absence of gravity. It was known that the geometrical structure of the web of an orb-weaving spider provides a good measure of the condition of its central nervous system, and it was thought that since spiders sense their own weight to judge how thick to weave their webs, and use both the wind and gravity to sense when to begin construction, the lack of gravity in space would pose some serious issues for the arachnids. NASA agreed to the idea, and in 1973 two garden spiders called Anita and Arabella, along with the experimental apparatus, flew aboard the Skylab 3 mission. Though their initial efforts were distinctly confused, both spiders managed to spin sensible webs by the end of the mission, even though they were slightly finer than on Earth. Though they both died from dehydration during their flight, Anita and Arabella are preserved at the Smithsonian Air and Space Museum in Washington DC. More recently, in 2008 and 2011, orb-weaver spiders were selected for further web-spinning experiments aboard the International Space Station (ISS), and a red-backed jumping spider named Nefertiti was sent to see if it could still hunt effectively in zero gravity. All the spiders showed remarkable adaptability.

SPACE SWIMMERS

PERISHED

23 OCTOBER 2012 - 60 DAYS



Medaka, or Japanese rice fish, are ideal for experiments. Not only hardy and simple to rear, they also have transparent skin, making it easier for researchers to see what's going on inside their bodies. They have been a popular choice for marine experiments in space, carrying the distinction of having been the first vertebrate to successfully mate in orbit, with fry hatching on the Space Shuttle Columbia in 1994. When the Japan Aerospace Exploration Agency wanted to conduct an experiment to see how fish would respond to radiation impact, bone degradation and muscle wastage, medaka were the natural choice. The medaka reached the ISS in 2012 and were transferred to the station's Aquatic Habitat, a purpose-built aquarium with an automatic feeding system, water circulation system and LED lights to represent day and night. Results from this and subsequent experiments have been interesting. For humans it takes at least ten days for any space-related bone symptoms to be revealed, but the medaka started losing bone density almost immediately when they arrived in orbit.

ANIMAL MILESTONES

Survived
Died

Fruit flies
20 February 1947
The first animals in space were fruit flies launched on a captured Nazi V-2 rocket to a height of 109 kilometres (68 miles).

Albert II
14 June 1949
The first monkey in space was the American Albert II.

Laika
3 November 1957
This Soviet space dog was the first animal to orbit Earth.

Ham
31 January 1961
Ham the chimp was the first hominid to be sent into space. He proved organisms could operate successfully in microgravity.

Yuri Gagarin
12 April 1961
The first human in space was Yuri Gagarin, who orbited Earth once.

Félicette
18 October 1963
French scientists launched the first cat into space in 1963.

Arabella and Anita
28 July 1973
These two spiders demonstrated that they could spin webs even in microgravity.

Tortoises
14 September 1968
The first animals to circle the Moon were two tortoises aboard Zond 5, along with other smaller organisms.

Chickens
13 March 1989
On STS-29, 32 chicken embryos were taken to space, with a handful managing to hatch successfully.

Guinea pigs and others
5 October 1990
China's first animal taikonauts were guinea pigs, along with dozens of other animals and plants.

Newts
18 March 1995
Japan's first animals in space were a species of newt aboard its Space Flyer Unit.

Roundworms
16 January 2003
The last flight of Columbia carried several species, including nematodes, or roundworms.

Fish
23 October 2012
A species of medaka fish resided on the ISS in a rudimentary aquarium.

Pishgam
28 January 2013
Iran claims to have been the latest nation to launch a primate, although the validity remains suspect.

NUMBER OF NOTABLE CREATURES LAUNCHED INTO SPACE

Figures calculated based on the best available information

32
25
1
1

1940 1950 1960 1970 1980 1990 2000 2010 2020

AMPHIBIAN BALANCING ACT

BOTH PERISHED

Two very different space adventurers were ready to spring into action in 1970, all in the name of understanding the effects of space travel and weightlessness on humans. The Orbiting Frog Otolith – 'otolith' refers to the frogs' inner-ear balance mechanism – spacecraft contained two bullfrogs that were in for a wild ride. After having surgery to implant electrodes into their thoraxes and vestibular systems – a part of the nervous system within the inner ear that helps maintain balance – the frogs' nerves connecting their limb muscles were cut to prevent them from accidentally removing the electrodes. They were then placed in water for the duration of the flight to cushion them from vibrations and to keep them cool. Interestingly, after a bumpy first few days, by the last day of the six-day flight the frogs' vestibular systems had returned to normal, suggesting that they acclimatised to their space environment. Unfortunately for the frogs, they never returned to Earth.

9 NOVEMBER 1970 - SIX DAYS

A TRAGEDY'S ONLY SURVIVORS

SURVIVED

16 JANUARY 2003 - 16 DAYS

Space Shuttle Columbia had served for roughly 22 years, completing 27 missions before its 2003 flight. On this fateful last voyage, launch and orbit appeared to go well. However, the spacecraft and its seven-astronaut crew were tragically lost on re-entry. Caused by a hole that had been punctured in one of Columbia's wings during takeoff 16 days earlier, the disaster ultimately ended the Space Shuttle program. The initial seven-month investigation of the Columbia disaster yielded nearly 85,000 pieces of the spacecraft, including many of the 60 science experiments, some of which involved animals. Of the fish, insects, spiders, bees and silk worms that had been aboard, only the nematode worms survived. Hundreds of microscopic nematodes were found inside Petri dishes held in six canisters within a four-kilogram locker. It was the locker's robustness, reinforced specifically to protect the materials inside, that saved the nematodes. Yet the worms found were not the original survivors. As nematodes have a life cycle of seven to ten days, by the time they were discovered the worms were fourth or fifth-generation descendants of the original spacefarers. From the amazing survival of the nematodes, astrobiologists learned that life could potentially travel between planets by natural means.

"Astrobiologists learned that life could potentially travel between planets"

HARDIEST ANIMAL ON EARTH, AND IN SPACE

SURVIVED

14 SEPTEMBER 2007 - 12 DAYS

If you found a tardigrade floating in space, you would assume it was alien. Less than one-millimetre long, tardigrades are short, plump and puffy creatures with four pairs of legs that each end in claws or sucking discs and a tubular mouth ringed by teeth-like structures called stylets. Known as 'water bears' or 'moss piglets', they're found in almost every environment on Earth, and are remarkably hardy. For this reason, in 2007 three groups of tardigrades were sent into space on the European Space Agency's Foton-M3 mission. The first group were exposed to the vacuum of space, the second group vacuum plus an unhealthy dose of solar radiation and the third vacuum plus full solar radiation exposure. Staggeringly, when returned to Earth and rehydrated, the first group showed no signs of damage. The two groups exposed to solar radiation fared worse, but even in the group exposed to a full dose of solar radiation, three tardigrades were successfully reanimated, making them the first animals to survive in outer space. It's for this reason some people believe tardigrades are alive on the Moon – in April 2019, the Israeli spacecraft Beresheet crash-landed on the Moon carrying thousands of the tiny creatures.

A Tardigrades are indisputably the hardiest creatures on Earth and in space

© Getty Images

FOCUS ON

X-RAY VIEW SHOWS HOW SUPERMASSIVE BLACK HOLES SPEED UP PARTICLES IN JETS

Blazars are powered by immensely active galatic centres that fire beams of particles into space

Reported by Keith Cooper

Peering deep into the heart of a blazar, astronomers have learned how particles are being accelerated to close to the speed of light, racing away in a jet emanating from near the blazar's monstrous supermassive black hole. Blazars are quasars seen head-on; a quasar is an extremely active galactic nucleus (AGN) that is powered by a black hole accreting vast amounts of matter. The matter circles around the black hole in an accretion disc, where conditions are so extreme that the disc shines at millions of degrees. Tightly entwined magnetic fields wrapped up in the disc are able to funnel away some of the material in tightly collimated jets shooting away from the centre of the accretion disc in either direction. The charged particles in these jets spiral around the magnetic field lines, emitting something called synchrotron radiation. It's this radiation that produces most of the light that we see shining from quasars and blazars, in which one of the jets points towards Earth.

A blazer as seen head-on to Earth

Astronomers have used NASA's Imaging X-ray Polarimetry Explorer (IXPE) satellite, which launched in December 2021, to observe the blazar Markarian 501, located about 456 million light years away from Earth. IXPE is particularly talented at observing the polarisation of light, which refers to the orientation in which light waves are seen to preferentially oscillate. In a blazar, the polarisation is influenced by the strength and structure of the blazar jet's magnetic field. IXPE's observations can shed light on the blazar's magnetic environment, which in turn can provide clues as to what's accelerating the particles in the jets.

If turbulence or instabilities in the jet were giving energy to the particles, scientists would expect the polarisation to be weak and at random angles, indicating a relatively disorganised magnetic field. But previous measurements of the polarisation at optical and radio wavelengths have only been sensitive to the parts of the jet farther away from the black hole, seeing the particles days or even weeks after they have been accelerated – too late to be conclusive. However, X-rays are produced closer to the source of acceleration, and their polarisation is indicative of whatever mechanism is accelerating the particles in the jet. "How close the X-rays we see with IXPE are depends on the spectrum of the source, but in any case they are very close," Ioannis Liodakis, an astronomer at the University of Turku in Finland and lead author of the new research, said.

The Markarian 501 observations, made in March 2022, measured the level of X-ray polarisation to be ten per cent, which is about twice as much as seen in optical light farther up the jet, away from the black

hole. The X-ray polarisation angle was also shown to be consistently parallel to the jet close to the jet's source. Scientists had predicted this; the level and turbulence of polarisation seems to correspond to the wavelength of light emitted, with shorter wavelengths closer to the source having higher, more linear polarisation than the longer wavelengths farther out in the jet. These observations seemingly rule out turbulence or plasma instabilities as mechanisms for accelerating the particles because these processes wouldn't produce the highly structured magnetic fields needed for the observed level of X-ray polarisation. As a result, the researchers think that a shock wave in the jet is the most likely mechanism for accelerating the particles.

That leads to another puzzle – what caused the shock? "There are a few ways to make a shock in the jet," Liodakis said. "Based on our limited understanding, two ways are common. The first has to do with environmental reasons – changes in pressure and density of the external medium can lead to the creation of shocks. The second way is to have plasma moving at different velocities, and a shock can be created when a slow region collides with a faster one." If the shock theory is correct, scientists predict that at X-ray wavelengths, the polarisation angle will rotate; future observations with IXPE may be able to detect these rotations and support the team's conclusions.

The new X-ray results, in combination with the previous optical and radio polarisation measurements of Markarian 501's jet, show how important multi-wavelength observations are for getting a complete picture of what's going on. Similarly, earlier this year the Event Horizon Telescope measured the radio polarisation of another blazar jet, finding it to be corkscrew-shaped. Now, with IXPE's X-ray capabilities, astronomers have the tools to scrutinise blazar and quasar jets at all scales to better understand how the universe's ultimate particle accelerators function.

1 Jets High-energy jets shoot out in opposite directions, perpendicular to the accretion disc. They can be very bright if seen head-on.

2 Supermassive black hole All the energy ultimately comes from the black hole's incredibly strong gravitational field.

3 Accretion disc Material orbiting the black hole at close range releases huge amounts of energy as it gradually spirals in.

4 Dusty torus The accretion disc is surrounded by a larger, doughnut-shaped region of dust-like material that can obscure the view.

5 Viewing How much activity an observer actually sees depends on their viewing angle relative to the disc, torus and jets.

SUPERMASSIVE EXAMPLES

Leo I Dwarf Galaxy

Although this tiny galaxy is only about 20 million solar masses in total, its central black hole is proportionately huge at around 3 million solar masses.

Centaurus A

This huge elliptical galaxy, just 13 million light years away, is a powerful radio emitter thanks to the 55-million-solar-mass black hole at its centre.

NGC 7727

The product of two merging galaxies, NGC 7727 still retains two supermassive black holes, of 154 and 6.3 million solar masses, 1,600 light years apart.

Abell 2261

This cluster of galaxies is estimated to have a black hole of up to 100 billion solar masses near its centre. Its exact location continues to elude detection.

© NASA / ESO / Wiki: Scott Anttila / Illustration by Adrian Mann

MYSTERIES OF THE UNIVERSE

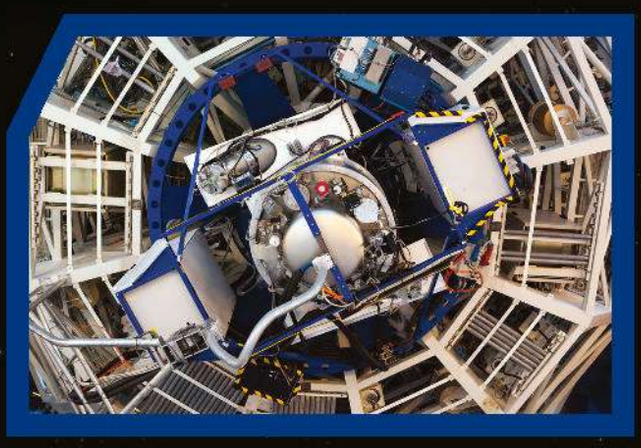
UNRAVELLING ANCIENT SOLAR SYSTEMS

The discovery of a white dwarf with high levels of lithium and potassium has provided fresh insights into early planet formation

Reported by David Crookes

For nine years, the Gaia spacecraft has been hard at work creating a highly detailed 3D map of the Milky Way. It was launched with the aim of surveying more than one per cent of the galaxy's 100 billion stars. It has made many crucial discoveries, helping scientists better understand how the galaxy was formed and how it's changed over time. Although there's still four years to go, the mission has already found strong non-radial tsunami-like starquakes in thousands of stars as well as quasars, exoplanets and even the first supernova outside of the Milky Way. But now we can add another discovery – one which is perplexing scientists. Astronomers have spotted a white dwarf star that appears to be about 10 billion years old, and further studies point to a Solar System that was very different to any previously found.

"This star was identified as a high-confidence white dwarf candidate in a large catalogue of stars identified by Gaia," explains Abbigail Elms, lead author of the study. "It was noticed that this white dwarf is unusually red and faint, confirmed by plotting it on a Hertzsprung–Russell diagram and comparing it to other white dwarfs identified by Gaia. The fact that this star is very red and faint hints that it is very old and probably very cool." By observing the white dwarf, called WDJ2147-4035, Elms and her team were able to gather more data. For starters, they made use of the X-Shooter instrument on the Very Large Telescope at the European Southern Observatory in



© NASA; ESO

> The white dwarfs were analysed using the X-Shooter spectroscopic instrument on the Very Large Telescope in Chile. It can record the entire spectrum of a celestial object in one shot

WDJ2147-4035 BY NUMBERS

90 LIGHT YEARS
Distance of the white dwarf from Earth

10.7 BILLION
Approximate age of WDJ2147-4035 in years – that's 3.1 billion years after the Big Bang

500 MILLION
Age of the newest star system in the Milky Way

4.6 BILLION
Age of our Sun

10.2 BILLION
Number of years the white dwarf has spent cooling

97
per cent of all stars will become white dwarfs

THREE
main metals found in the white dwarf: sodium, lithium and potassium

"The fact that this star is very red and faint hints that it is very old and probably very cool"
Abbigail Elms

Chile, which allowed them to obtain the star's spectra, thereby giving them more information about its chemical composition, temperature and intrinsic luminosity.

"X-Shooter is the best spectroscopic instrument to use for observing white dwarfs because it's very efficient and covers a large spectral range, including all optical wavelengths, in a single exposure," says Elms, who is a PhD student at the University of Warwick. "It's designed to maximise sensitivity over its spectral range." It proved so effective that it was able to highlight a very unusual make-up. As well as discovering sodium and potentially carbon, the team noted very high levels of lithium and potassium. "This was the first spectra ever taken on this white dwarf, so we were able to identify and confirm it is metal-polluted," Elms explains. "We then used a state-of-the-art model atmosphere code with microphysics improvements specifically tailored for cool white dwarfs to determine the star's parameters, such as its temperature, surface gravity, atmospheric composition ratios and cooling age."

The abundance of lithium and potassium set minds racing. "We know this white dwarf is lithium and potassium-rich compared to typical bodies in our Solar System," Elms says. "We used our model atmosphere code to determine the abundances of the elements present in the white dwarf's atmosphere, then we were able to compare them with the abundances of metals found in other Solar System bodies." Such high levels were unheard of in white dwarfs – no previously studied star of this type has been shown to have such amounts. Yet here was a white dwarf that had burned brightly at a time when the galaxy was far less metal-rich than today. It had somehow managed to become metal-rich in an environment that shouldn't have been so rich in metals. It prompted scientists to investigate how it gained such a composition.

"Astronomers consider any element that isn't hydrogen or helium a metal," Elms explains. "If a galaxy is 'metal-rich', it has an abundance of elements heavier than helium, so it's capable of forming planets and planetary systems with a diverse chemical composition. "If a galaxy is 'metal-poor', it has a deficit of elements heavier than helium, so it's much rarer to find planets and planetary systems enriched with metals. This white dwarf is unusual because we cannot explain why it's so lithium and potassium-rich. It's more than 10 billion years old so its planetary system is also this old."

Metals in the Milky Way have built up over time – they're created by stars in their dying years and are then blasted into space. Rewind 10 billion years and far fewer stars had evolved and ended up as supernova explosions, so you wouldn't expect a star as old as WDJ2147-4035 to be so rich in lithium and potassium because such metals were not in abundance. "The early galaxy was less metal-rich than it is

Our Sun formed from the collapse of a giant molecular cloud. It's now at stage four shown here, but it will become a white dwarf in 5 billion years

Gaia has been creating a 3D map of the Milky Way, leading to groundbreaking insights into the galaxy's composition, formation and evolution

today, as metals are created and distributed through galaxies when evolved stars die and explode as supernovae – lots of time needs to have gone by. This is why young galaxies aren't metal-rich," Elms says. By way of comparison, Earth is 4.5 billion years old, and this white dwarf was around for billions of years before our planet was born.

Scientists say the star would have gained such elements by accreting planetary debris – after all, white dwarfs are made of hydrogen or helium, so lithium and potassium have to be accreted. This suggests that planets were forming at a time when the galaxy was very young and that they could emerge in conditions dissimilar to our own Solar System. WDJ2147-4035 had been gobbling them up.

"White dwarfs are stellar remnants of stars with similar masses to our Sun," says Elms, beginning to explain why the planets are the most likely source of lithium and potassium. "These stars are born and live the majority of

SOME WHITE-HOT THEORIES

Scientists are struggling to explain why the white dwarf is so rich in lithium and potassium

The age is incorrect

There's a chance that WDJ2147-4035 isn't 10.7 billion years old. This age is largely based on its temperature, but a paper published in July 2022 suggests ultracool white dwarfs may actually be warmer and therefore younger. Astronomers in this case have used the best and most sensitive spectroscopic instrument available to them.

Metals from elsewhere

Could the lithium and potassium not have come from the consumption of debris from younger star systems? Other planetary systems would be orbiting other stars. If WDJ2147-4035 is accreting debris from a younger system, the gravity of the white dwarf would have caused a merger with the stellar host of the alternative planetary system.

Something else entirely

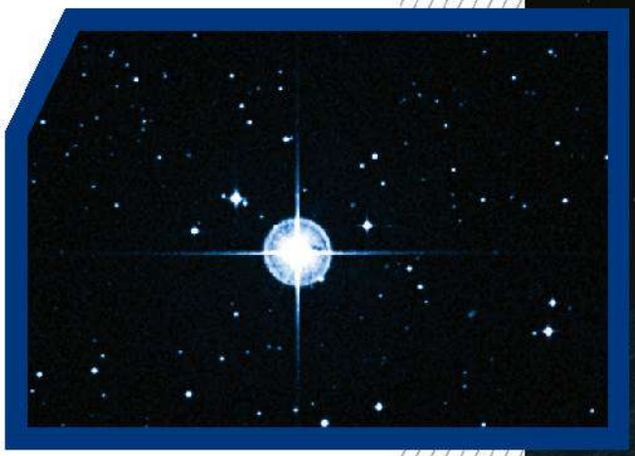
The most likely explanation is that at this stage, those studying WDJ2147-4035 have not come up with a theory. "I cannot comment further at this time," says the study's lead Abbigail Elms. Only by gaining more data about the conditions of the galaxy can headway be made, and you can be sure that they're working hard to find answers.

© ESA; Getty Images

4

their lives in the main sequence phase – which our Sun is in now – where they fuse hydrogen to helium in their cores and are stable for a certain amount of time.

"Eventually, their supply of hydrogen runs out, resulting in the cessation of fusion and therefore outward pressure. The star becomes unstable and enters the red giant phase, where it increases in radius and looks visually redder. This is a relatively short phase, as the star expels its outer envelope of material and only the core of the star remains. The core is what we call a white dwarf, and it has a thin atmosphere which consists only of hydrogen and/or helium."

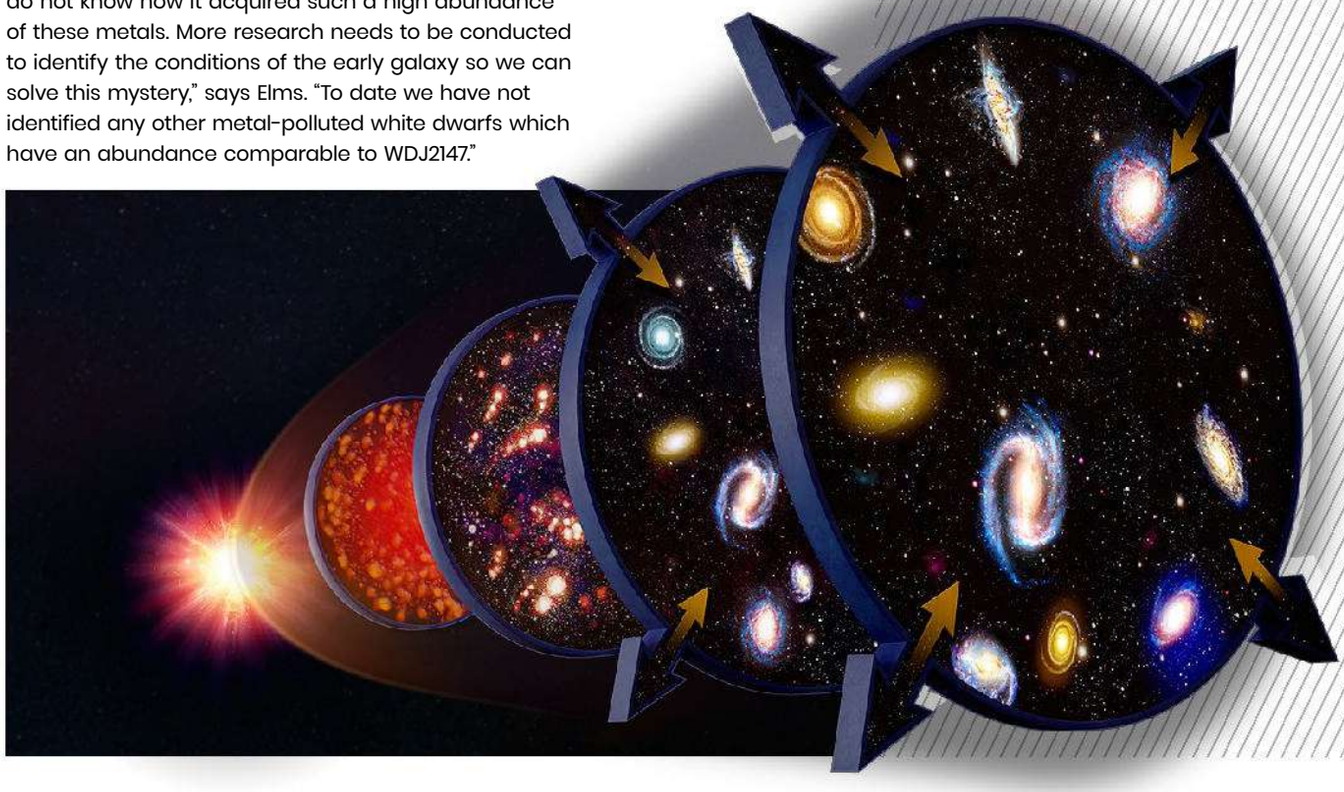


To observe such high levels of lithium and potassium today suggests that a planetary system which orbited the star before it died was not entirely destroyed. The remains of that system have been falling into the white dwarf star ever since. What we're seeing is an ancient solar system. If we detect metals then we know it has come from an external source," Elms says. "This is how we know planetary debris is the source of the lithium and potassium."

Scientists are still some way off resolving the mystery. They've drawn a blank so far, despite having explored many theories of metal enrichment in the early galaxy in the hope of working out exactly how the white dwarf's planetary debris has such an exotic composition. The aim now is to find a scenario that could explain the exact chemical composition of the white dwarf, taking into account its emergence in what would have been a metal-poor environment. "It's intriguing because this white dwarf and its planetary debris are 10 billion years old, unusually lithium and potassium-rich, and yet we do not know how it acquired such a high abundance of these metals. More research needs to be conducted to identify the conditions of the early galaxy so we can solve this mystery," says Elms. "To date we have not identified any other metal-polluted white dwarfs which have an abundance comparable to WDJ2147."

Subgiant star HD 140283, or the Methuselah star, is the oldest in our galaxy at about 13.1 billion years. It's metal-poor and 190 light years away

The Solar System formed about 4.5 billion years ago, but the planetary system surrounding the white dwarf being studied emerged 10.7 billion years ago



© University of Warwick/Dr Mark Garlick; ESA/Hubble

A TALE OF TWO STARS

Scientists studied two ancient white dwarfs that showed rocky planets were able to form

1 Cool blue
WDJ1922+0233 has a cool surface temperature but appears blue because of an unusual helium-hydrogen atmosphere. It's slightly younger than its red counterpart WDJ2147-4035.

2 Old and metal-polluted
WDJ2147-4035 has an ultracool surface temperature and would be pure helium if it wasn't being enriched by lithium, potassium and sodium. It's unlike anything known in our galaxy.

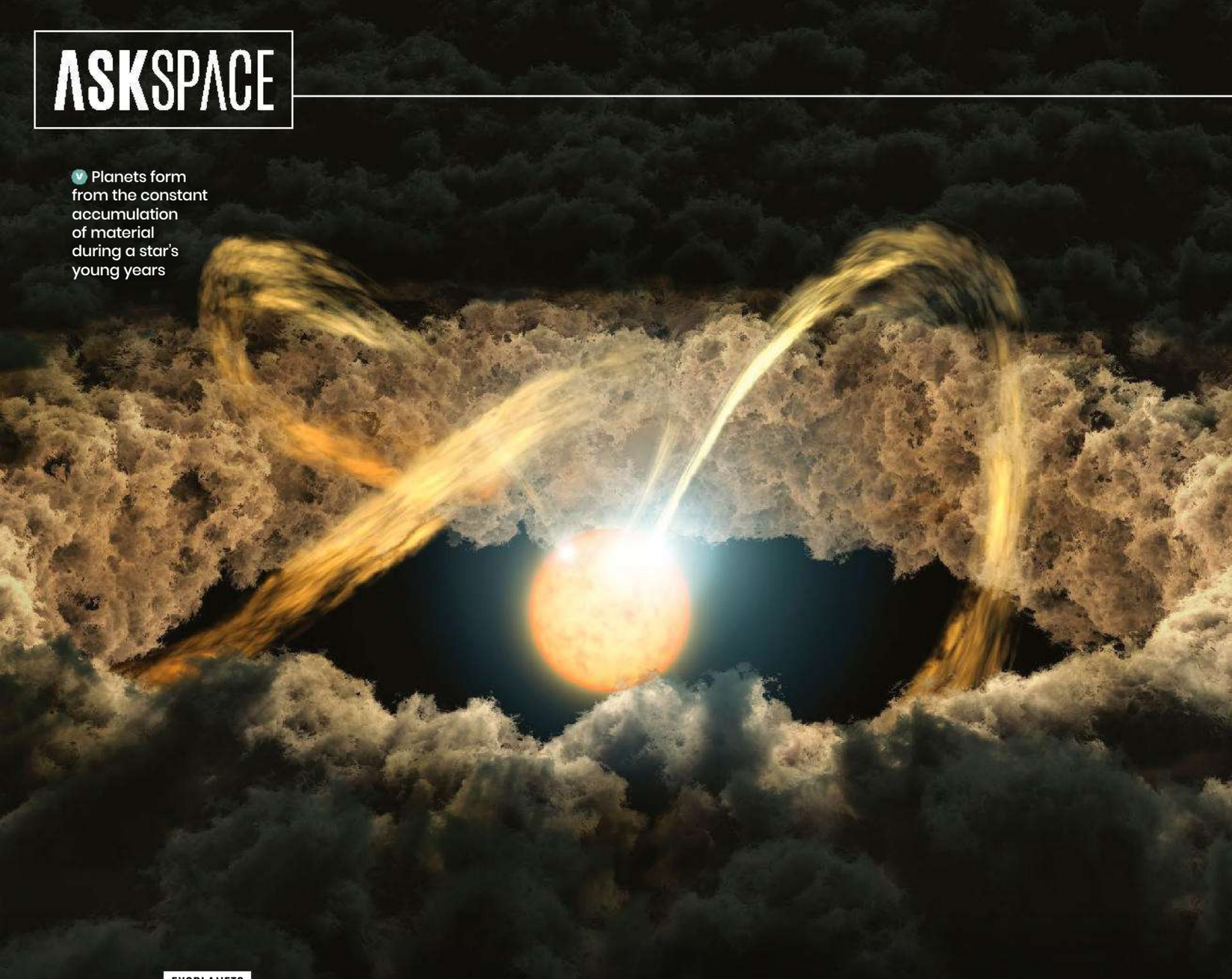
3 Planetary accretion
The metal-rich nature of WDJ2147-4035 is due to the accretion of planetesimals. This is from an old planetary system that survived the evolution of the star into a white dwarf, yet the universe was less metal-rich back then.

4 Earth-like planets
Scientists have found that WDJ1922+0233 is being polluted by material that's similar in composition to that of Earth's continental crust. It shows there are other planetary systems with bodies similar to our planet.

And this isn't the only discovery on the researchers' minds. As part of the same study, the scientists also focused on a second white dwarf, WDJ1922+0233, which is a little younger than WDJ2147-4035. This second example pointed to an early solar system that had more similarities with our own. This ancient system was found to have been polluted by planetary debris of a similar composition to the Earth's rocky crust. The two white dwarfs together are helping resolve the mystery of planetary formation in the earlier years of the universe – one by showing that a solar system could form within a very different environment to the one that we have long assumed and another by showing that solar systems similar to our own formed many more billions of years ago.

"This study sheds light on what our galaxy was like in the past, and it's an important piece of the puzzle in understanding our galaxy's evolution and early planetary formation," Elms says. "We found that the planetary debris that polluted the white dwarf WDJ1922+0233 likely had a composition similar to Earth's continental crust. This is an interesting and intriguing connection to our Solar System because it suggests there was possibly a planet with a similar chemical composition to Earth's continental crust in the planetary system of WDJ1922+0233 9 billion years ago. This tells us that our galaxy had material similar to the Earth's continental crust 9 billion years ago, which is way before Earth was even formed." Although the findings were reported in the *Monthly Notices of the Royal Astronomical Society*, it's clear the study is going to continue for some time yet. WDJ2147-4035 in particular is a rare find, and it is so unlike anything else in our Milky Way that it begs for ongoing research.

David Crookes
Science and technology journalist
David has been reporting on space, science and technology for many years, has contributed to many books and is a producer for BBC Radio 5 Live.



Planets form from the constant accumulation of material during a star's young years

EXOPLANETS

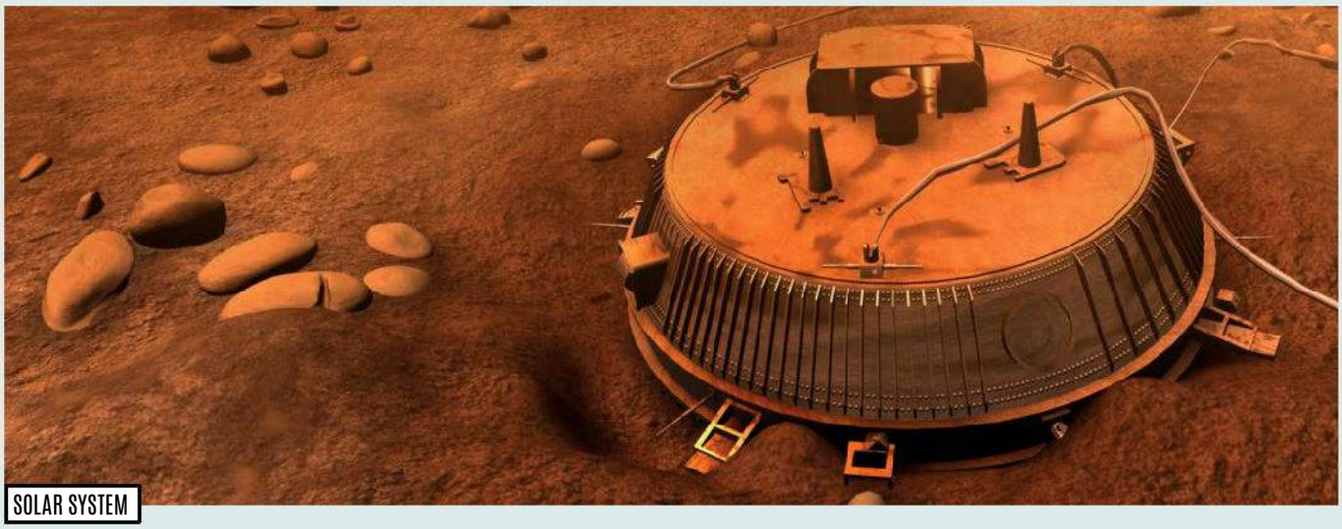
Do smaller stars generally host smaller planets?

The Sun is a typical star, but many smaller stars exist in the universe. Red dwarfs are the smallest stars, measuring about 10 to 50 per cent the size of the Sun. Over the past two decades, many planets have been detected around such red dwarf stars. Surprisingly, these worlds are not much different from those found around Sun-like stars. Many of them are rocky, Earth-like planets, like the seven planets detected around the TRAPPIST-1 star and the two planets around Proxima Centauri, the closest star to the Sun.

On the other hand, a significant fraction of them are large gas giants like Jupiter. In fact, some red dwarf stars host planets ten times as big as the king of the Solar System, yet how these worlds form remains an unsolved mystery since these small stars do not have enough material in the discs around them to form such big planets.

However, it is possible that their discs had much more material when these stars were very young. If this is the case, then these big discs would fragment – in other words break up into pieces – due to their own gravity, and quickly form giant planets. Hopefully future observations of the atmospheres of such planets from dedicated space telescopes, like the James Webb Space Telescope, will reveal chemical signatures of their formation mechanisms.

Dr Dimitris Stamatellos, associate professor at the Jeremiah Horrocks Institute



SOLAR SYSTEM

What Earth-like features does Titan have?

Titan presents unique geology for an icy satellite, mainly due to the presence of a thick atmosphere. Previous to the Cassini-Huygens mission, Titan's surface was hidden by its hazy orange atmosphere. The Cassini spacecraft and the Huygens probe unveiled an exotic but Earth-like world in many respects. Titan was found to possess vast dune fields, equatorial mountains and even lakes and seas at the poles. Titan is the only extraterrestrial body in our Solar System to possess standing bodies of liquid on its surface and is one of only three places in the Solar System, along with Earth and Mars, which we know to possess or have possessed an active hydrologic system, albeit with methane rather than water.

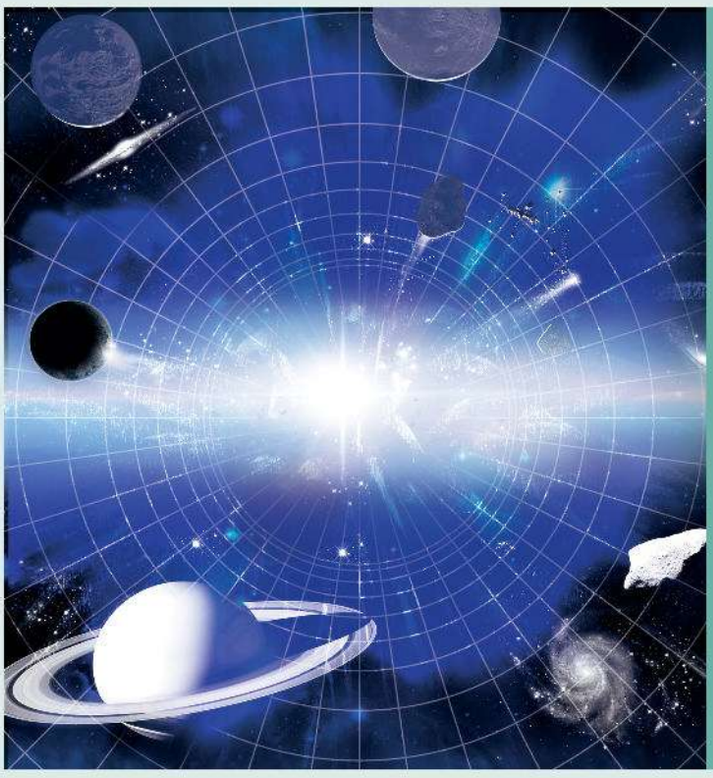
In a recent publication, my colleagues and I suggested that Titan's small lake basins with raised rims - some even surrounded by rampart features – share morphology and similar explosive origins analogous to lake basins formed as a result of terrestrial phreatic and phreatomagmatic explosions, such as on Mars.

We suggested that these small lake basins with raised rims, such as Winnipeg Lacus and its surrounding lakes, are craters that are the result of explosive eruptions due to phase transitions of liquid molecular nitrogen in the shallow subsurface.

Dr Giuseppe Mitri, senior researcher at the International Research School of Planetary Sciences

A The Huygens lander reached Titan's surface in 2005

The expansion of the universe reveals its age



COSMOLOGY

How do we know the universe's age?

After Edwin Hubble discovered the universe's expansion, scientists deduced that if the universe is currently getting larger, it must have once been much smaller. Constraining the age of the universe involves understanding the expansion history of the universe; the universe's expansion rate is ultimately determined by its contents.

Over the past several decades, scientists began to measure the contents of the universe, thus constraining its expansion history. This was achieved using various astronomical observations, especially measurements of the universe's first light, the cosmic microwave background. Given measurements of the universe's expansion rate today, cosmologists can calculate the amount of time the universe has expanded, giving the figure for the age of the universe as 13.8 billion years.

Zhili Xu, research fellow at Indiana University

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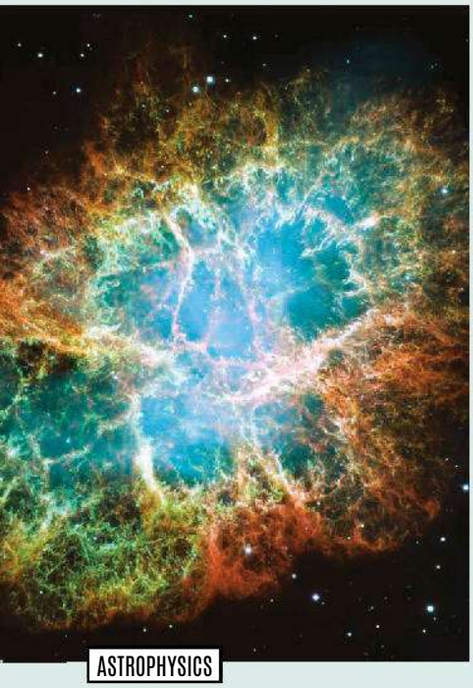


ASTROPHYSICS

How close would a supernova have to be to destroy life?

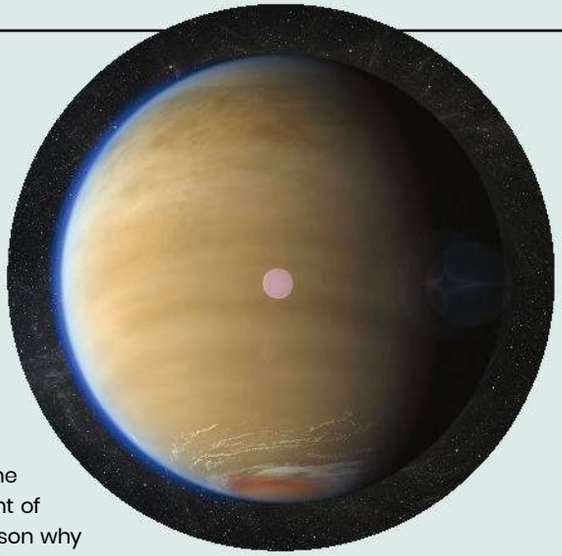
If a supernova were to go off within about 30 light years of us, that would lead to major effects on Earth, possibly mass extinctions. X-rays and more energetic gamma rays from the supernova could destroy the ozone layer that protects us from solar ultraviolet rays. It could also ionise nitrogen and oxygen in the atmosphere, leading to the formation of large amounts of smog-like nitrous oxide in the atmosphere.

Supernovae happen about once every 100 years in the Milky Way. But the Milky Way is a big place – roughly 100,000 light years across. Given that, and the fact that the Sun is near the outskirts of the Milky Way where few stars massive enough to become supernovae are born, having a supernova within 30 light years of the Sun should, on average, happen only once every 100 million years.

Dr Mark Reid, senior radio astronomer at the Harvard-Smithsonian Center for Astrophysics

MOONS

Why are there no gas moons?



Of all the moons in our Solar System, only one, Titan, has an appreciable atmosphere. But even Titan is mostly made of rock and ice, which doesn't constitute it as a 'gas moon'. In contrast, planets like Jupiter and Saturn are made mostly of hydrogen, with the primordial gas making up 90 and 94 per cent of their respective compositions. This is the reason why they are regularly referred to as 'gas planets'. The early Solar System contained lots of hydrogen, but because the gas is very light, only really large planets could hold on to it. Jupiter and Saturn began life as solid bodies and grew to about ten times the mass of Earth. At that point they were able to capture and hold onto the hydrogen that permeated the young Solar System.

However, because none of the moons in our solar neighbourhood grew to a great enough size, none of them managed to capture any hydrogen. Titan successfully captured some heavier gases, which have given this moon its atmosphere. However, similar moons such as Ganymede and Callisto do not have an atmosphere, even though the former is bigger than Titan, while Callisto is roughly the same size. The reasons why Ganymede and Callisto do not have atmospheres, though, are still unclear.

Professor Francis Nimmo, professor in the department of Earth and planetary sciences at the University of California, Santa Cruz

▲ Moons in the Solar System are mostly ice and rock, but none of them are mainly gas

▼ Other bubble universes could be surrounding our own

ASTROPHYSICS

What exists outside our observable cosmos?

There are some questions that science just can't answer. This is one of them. Humanity, in our three-dimensional reality, is confined to this universe. We can't experience what is beyond through any means known to science. Imagine life on the surface of a vast balloon. If all you know is the balloon's surface, you can identify no centre on that surface. You can't see what is inside that surface or external to that surface. While observational science doesn't allow us to get to an answer from here, theorists have put forward a variety of ideas.

One possibility is that there is a vast quantum foam from which bubble universes regularly come into and go out of existence. Some scientists point to the seeming fine-tuning of our universe, which makes life possible, as evidence that we are in one of many universes of many different configurations. This probability-based argument doesn't make multiple universes real, however, and it is just as possible that there is nothing at all beyond our universe.

Pamela Gay, senior education and communication specialist and senior scientist for the Planetary Science Institute

ASTRONOMY

What do radio observations reveal about the centre of the Milky Way?

Radio is brilliant. It allows us to peer much more deeply. It doesn't get stopped by dust, so you can see everything. We do see something interesting in the Milky Way. All that dust has gone, so it's not a problem. But the view is very different. The centre of the Milky Way is aglow, and this isn't starlight. This is a light called synchrotron radiation, and it's formed from electrons spiralling around cosmic magnetic fields. The plane is aglow with this light.

We can also see strange tufts coming off it and objects which don't appear to line up with anything that we can see with our own eyes. Radio waves have a wavelength that's long, and that makes their resolution poorer. I've spent a long time calibrating it, running millions of CPU hours on supercomputers and trying to understand that data. And with Murchison Widefield Array (MWA) data, we've performed a survey of the entire southern sky – the GaLactic and Extragalactic All-sky MWA survey (GLEAM). The resolution has gone up by a factor of a hundred. We now have a technicolour view.

Natasha Hurley-Walker, International Centre for Radio Astronomy Research, Curtin University, Australia

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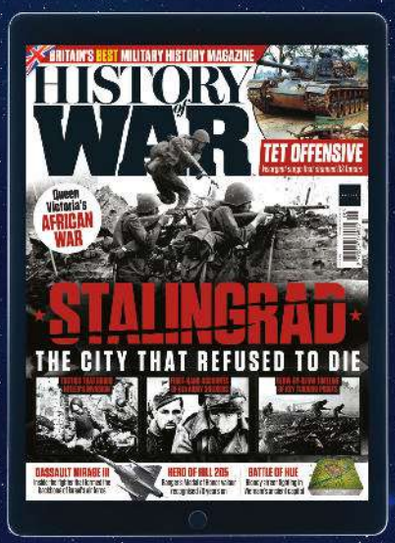

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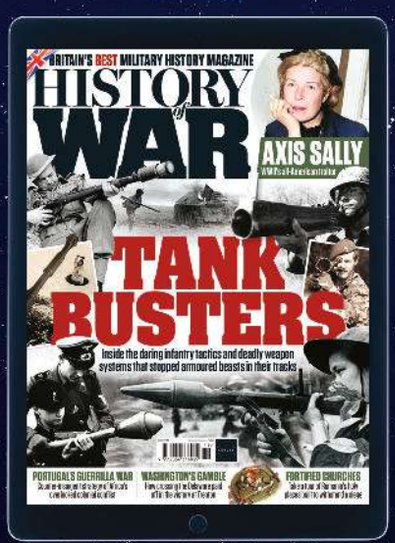
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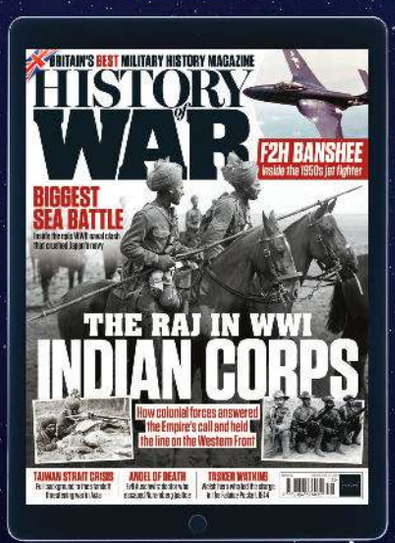
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ISSUE 112

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ASTROPHO
FOR BEGINNERS

Learn the art of photographing the night sky with All About Space

TOGRAPHY

The sky at night is one of the most awe-inspiring things to view, and whenever a natural spectacle like this amazes us, one of the first urges is to capture an image of it. However, taking great photos of the night sky is harder than it looks. In fact, astrophotography may be more challenging than almost any other kind of photography.

As an astrophotographer striving to capture compelling images of the night sky, you need to build up your reserves of patience, be willing to drive for miles when you'd rather be tucked up in bed and be prepared to stay awake all night. Successful shoots will also need a large amount of planning and a good understanding of the equipment you're using. Then there's the science. Decent astronomical and meteorological knowledge is definitely an advantage that rapidly becomes a necessity if you want to take close-up portraits of the Moon and stunning images of distant celestial objects.

You can't take great shots of the heavens on any given night of the year, which is why one of the first virtues astrophotographers need is patience. For example, if there is any kind of cloud coverage, the stars will be obscured and great images are difficult to obtain, even with extensive equipment. This is one of the reasons why the stars often seem brighter on cold winter nights. At these times the low temperature is in part due to an absence of cloud, enabling heat to escape from Earth and disperse into the atmosphere.

Another reason for the vivid sparkles of winter skies is that the Sun drops below the horizon by a much greater degree than in summer. Though it's almost imperceptible to the naked eye, during the height of summer there is some degree of sunlight interfering with the clarity of the night sky for all but a few hours. Unfortunately we are at the mercy of the weather, which cannot be predicted too far in advance.

However, not all of the challenges faced by astrophotographers come down to the raw science of astronomy and meteorology. Human activity also greatly affects the chances of obtaining a clear view of the canopy of stars. For example, the summer months can present an additional problem if smog, general air pollution, dust particles and exhaust fumes gather in the atmosphere during a period of prolonged high temperatures and poor airflow. But this isn't the only kind of pollution astrophotographers have to contend with. An even bigger problem is light pollution, and it's the combined effects of these two pollutants that force those searching for the clearest views out into isolated and dark areas. It's this ongoing search for perfect conditions that often drives large-scale scientific observations hundreds of miles from the nearest major city.

The glow of several thousand lights burning all night long in the big cities affects the visual clarity of the starlight and also plays havoc with long camera exposures, presenting itself as an orange haze that competes for attention with the main attraction in the skies above. This is why the darker your observing site is, the better your results will be when it comes to photographing the night sky.

Astrophotography might seem daunting, but after this short guide you'll be imaging the night sky in no time. We'll guide you through what equipment you'll need, how to prepare it and how to start taking great images of the night sky and the celestial treasures that it holds.

KNOW YOUR EQUIPMENT

Here's a guide to the kit you'll need for your astrophotography adventures

There's nothing worse than being unprepared on your first venture into astrophotography. Whether you're picking a suitable dark site or choosing which equipment you need to take along, you're very likely to get frustrated without preparation. Before you get trigger-happy with the shutter, ensure you're ready to turn your lens to the night sky.

CCD camera

One-shot colour charge-coupled devices have red, blue and green filters built in, while monochromatic only work in black and white. One-shots need multiple images through each relevant filter before being composited together to get the finished result.

Tripod

We mostly associate tripods with telescopes, but if you're looking to take stable, wide-angle, long-exposure shots, fitting your DSLR camera to a tripod and a suitable mount is a must for great results.

Filters

You'll likely come across a variety of different filters – red, green, blue, yellow, polarising, H-alpha, H-beta, SII and O-III. Some can also assist with cutting out light pollution. The idea of a filter is to play up features on planetary surfaces as well as draw out the colours of nebulae and galaxies, picking out the colours that get lost when displayed through the eyepiece of your standard telescope.

Telescope

This is an astronomer's main tool, and while it's not essential for you to own one if you're more into your wide-field nightscapes, it might be worth investing in one since it can offer much more in the way of astrophotography. When choosing your telescope, ensure it's able to support a camera – the quickest indicator is to look out for a counterbalance, often found on reflectors.

T-mount

A T-mount or adapter enables you to attach your camera to your telescope securely.

Software

Once you've taken your images, it's likely you'll need to manipulate them to truly bring out the features of the objects you've shot. For this you can use Photoshop or more specialist software such as RegiStax.

DSLR camera

Digital SLR cameras are a great tool for astrophotography and are perfect for capturing star trails, dramatic Milky Way shots and other wide-field nightscapes. These cameras offer high resolutions even in low-light conditions and are able to capture deep-sky objects.

PLAN YOUR SHOOT

Check the weather

Keep a close eye on the weather if you're planning an overnight expedition. If cloud is predicted, you're likely to have an unsuccessful trip.

Take a mobile phone

As well as being useful for weather updates, a phone is essential if anything goes wrong – some of the best astronomy sites are lonely places.

Use a map

Study a map and familiarise yourself with your destination – don't just trust your sat nav to be able to guide you to some of the recommended locations.

Familiarise yourself

A simple star chart can be an excellent way of familiarising yourself with what the sky has to offer at each time of year.

YOU WILL NEED:

CAPTURE STUNNING NIGHTSCAPES

Shoot incredible night-sky shots with minimal equipment

We've all seen them – those stunning shots that show the world in motion in the form of star trails. These beautiful images are peppered with the stars of the Milky Way, as well as the eerie green glow of the northern lights snaking across the skies. They may look immensely difficult to shoot, but the good news is that this part of astrophotography is perhaps the easiest. Not only that, but you only need the bare minimum kit and know-how to get decent results. Of course, you won't get perfect images to rival those of seasoned astrophotographers straight away, but with plenty of practice and patience, you too could gradually get to their standard.

Many first-time astrophotographers struggle to achieve star-trail images. With the motion of our planet continually at play, it can often be difficult to figure out how to get a crisp shot. Additionally, and on the flip side of the coin, we have beginners wanting to stop the stars from moving so that they can image the rich star-filled Milky Way. To assist, **All About Space** has put together a guide for shooting in both instances.

GET A STAR-PACKED IMAGE

Easy steps for great results

Set up

First, ensure your camera is mounted on a solid tripod that's quick and easy to adjust. It should also be able to resist any wobbles caused by the wind and placed on flat, solid ground that's away from artificial light. Also avoid the natural light of the Moon and preferably shoot a few days before or after a new Moon.

Capture

In order to capture the Milky Way, you'll need to increase your camera's sensitivity. Ensure that you use a wide aperture, high ISO and shoot in RAW format to ensure quality. You may need to push your ISO up to 1600 or more to avoid long shutter speeds. To work out your shutter speed, divide 500 by your lens' focal length.

Edit

You can sharpen up your images using Photoshop's Noise Reduction filter. If you have taken two separate exposures of the land and sky, just stack them together and use a layer mask and the Brush tool to blend the frames together. You can also boost the colours and contrast by applying Curves and Color Balance tools.

SHOOT THE GALAXY

How you can image the majesty of the Milky Way

Without question, the Milky Way is one of the most impressive views during an evening of observing, as it weaves its way majestically across the night sky. Since our Solar System is positioned in this galaxy, it's easy to think that we have the opportunity to see it every night, provided there's no light pollution and the skies are free of cloud, but this isn't the case.

The Milky Way is best observed and photographed throughout the summer months, and especially in June, July and August. Since the nightly hours are shorter during the summer, the richest and most unhindered views of our galaxy will be very limited. When planning your shoot, you should aim to head out just after midnight for a good two to three hours. If you happen to be observing at a position closer to the equator, such as southern Brazil, Queensland or South Africa, you'll often get the best sights and shots of our galaxy.

Our galaxy is one of the most impressive sights in the night sky

CREATE A STAR TRAIL

Capture the world in motion with these easy steps

There are two ways to capture star trails. The first is to take a long exposure of usually up to an hour and the second is to capture several shots of a few seconds each. You can then combine these shots in software that enables stacking, such as Photoshop.

This second approach is likely to leave you with superior image quality compared to leaving your camera on an hour-long exposure time. Here your star-trail image will be of poorer quality since DSLR sensors are prone to overheating with prolonged use.

1 Prepare your camera

Get your camera in the correct position for test shots, ensuring your pole star is roughly at the centre of the frame.

2 Select the widest aperture

Set your camera to an aperture of around f/2.8 or whatever your camera's widest setting is. This boosts its light-gathering capabilities.

3 Set ISO and shutter speed

Once you've adjusted the camera's aperture, you'll need to set your camera to ISO 400 with a shutter speed of 30 seconds.

4 Shoot in RAW

Snap 20 to 30 frames in RAW format. When you process these, ensure that the same processing settings are applied.

5 Convert in post-production

In Photoshop, stack the frames as layers and convert all of them except the Background layer to Lighten blending mode.

6 Finalise the result

Your star-trail image is now almost complete. All that remains is to flatten the layers by going to Layer > Flatten Image.

PICK THE BEST SPOT

You might already have a location in mind where you're planning on starting your astroimaging. It may be your backyard is dark enough, or you might be heading over to farmland where you can escape the bright town or city lights. If you're undecided, your best bet is to attend a dark-sky park or reserve. Here's our pick of the top dark-sky sites untouched by artificial light.

Sark
Channel Islands

Galloway Forest Park
Newton Stewart, Dumfries and Galloway, Scotland

Brecon Beacons National Park
Wales

Aoraki Mackenzie International Dark Sky Reserve
South Island, New Zealand

Northumberland National Park, Kielder Water and Forest Park
Northumberland, England

Big Bend National Park
Texas

Cherry Springs State Park
Pennsylvania

Death Valley National Park
California

NIGHTSCAPES AT A GLANCE

Constellations
Exposure: **15 to 40 seconds**
Aperture: **f/2 to f/2.8**
Sensitivity: **ISO 800 to 1600**

Twilight landscapes
Exposure: **1 to 10 seconds**
Aperture: **f/2.8 to f/5.6**
Sensitivity: **ISO 100**

Auroras
Exposure: **3 to 30 seconds**
Aperture: **f/2 to f/2.8**
Sensitivity: **ISO 400**

YOU WILL NEED:

SHOOT CELESTIAL BODIES

Whether the Moon or planets are your target, here are the essentials you need to get the best outcome

Taking pictures of the Moon and bright planets isn't as difficult as you may think. Although you won't produce images as spectacular as the Hubble Space Telescope, with a little practice, patience and the right equipment, you'll be snapping portraits of lunar craters and the rings of Saturn in no time at all. To shoot the Moon, for instance, you'll need a small telescope of between four and six inches aperture. You'll also need a DSLR camera and an adaptor to fix it to the telescope where the eyepiece would normally go. You can use the screen on the back of the camera to check you have the object in focus. Because the Moon moves quite fast across the sky, you'll find it keeps moving out of the field of view. If you have a motorised telescope you can track it, otherwise you'll keep having to make adjustments.

As far as camera settings go, because the Moon is so bright you'll only need to use an ISO setting of around 300. Experiment with the length of exposure to see what works best for you and your camera, checking your results and adjusting as you go. Don't expose the camera for too long or you'll overexpose the brightest parts of the Moon. While DSLRs are ideal for imaging the Moon, webcams and CCDs are better for photographing the planets, as these are much smaller in the sky and not as bright.

The best planets to capture are Mars, Jupiter and Saturn when they are at their optimal size and brightness in the sky. Mercury is too small and too close to the Sun, while Venus is fairly dull to image thanks to its cloudy atmosphere. Uranus, Neptune and Pluto are too small and faint to take good pictures.

Webcams are useful because they enable the imager to create video files to take and combine as many of the best frames as possible. This is called stacking, and you can download free software to do this, such as RegiStax. Exposure times are short too, just tenths of a second, but because you're going to stack the images, they easily build up. The larger the telescope you have, the better you'll be able to see details such as dark regions on Mars, the belts of Jupiter's atmosphere or the rings of Saturn. Use a Barlow lens to help increase the magnification. If you're using a monochrome CCD, you'll also need to use colour filters in a filter wheel, which will produce image frames through either red, green or blue. You can then combine these in Photoshop to produce a final colour image.

The Moon in a few of its elegant lunar phases

Saturn is an easily recognisable night-sky object to capture

THE BASICS OF NIGHT-SKY SHOOTS

If you don't have a DSLR camera, don't worry. It's possible to take a good picture of the Moon through a telescope with just a compact camera or even the camera on your mobile phone. All you need is a telescope and a steady hand to take the shot. Hold the camera up to the telescope eyepiece, zoom in and start snapping. You might find your first attempts are horribly blurred. If you're using a camera phone there are actually special holders that attach to your telescope that can hold your phone in place while you take the picture. Storage space greater than five megabytes is now common on many phones.

YOU WILL NEED:

CCD

BRING THE DEEP SKY TO YOU

Further afield there are galaxies and nebulae galore – all perfect subjects for astrophotography

The Horsehead Nebula viewed in the constellation of Orion

Imaging deep-sky objects such as nebulae and galaxies is a little different to bright planets and the Moon. Because these objects are fainter, you'll need much longer exposures. Some of the most dedicated deep-sky photographers take exposures that last hours, or even days.

First, take flat fields and dark frames. Many deep-sky objects are so faint that any noise in the image can ruin the photo. For example, dust on the telescope or the camera sensor can look like huge blemishes in images. By taking a picture of a blank background and then subtracting this from your astro images in Photoshop, it'll remove any dust effect. Meanwhile, dark frames use a similar trick to remove thermal noise produced by your camera. Taking an exposure with the camera shutter closed will create a dark image containing only the thermal noise, which can then be removed.

To take a picture of the Ring Nebula, or Messier 57, which is one of the most famous nebulae in the summer skies, you'll need a large telescope of up to 200mm aperture. Schmidt-Cassegrain telescopes are useful for imaging because they have a long focal length and a small f-ratio, making them great for narrower fields of view so your nebula isn't a tiny fuzzy object hanging in a huge expanse of space. Because you'll want to take long exposures, the sky will be turning over your head as you do so, which means the object will move and your telescope needs to keep up with it. Make sure you have a good motorised telescope mount, but more importantly an autoguider. This can fix to the finderscope on your telescope and contains a little CCD camera to keep track of the object.

You may also want to think about using filters and a monochrome camera. If you have a one-shot colour camera that collects light of all colours at once, it'll speed up the imaging process, and this is probably best for beginners. Dropping in a different filter, such as hydrogen-alpha or oxygen-III, will collect light emitted by, for example, the many ionised oxygen atoms in the nebula.

Spiral galaxies are more complicated to image because they have bright centres and fainter arms. Brighter areas need shorter exposures, while the fainter arms need longer exposures, so it seems obvious you can't successfully image both at the same time. The trick is to take shorter exposures of the centre first, then take longer exposures of the spiral arms. The centre will be overexposed, but by masking the centre in Photoshop then combining with the shorter exposures that just show the centre, you can get the best of both worlds.

The Orion Nebula is another favourite object among astronomers

DSLR OR CCD

CCD

- Has less thermal noise
- Gets more detail from fainter objects due to cooling
- Enables mosaics to be made
- Detects infrared light
- Cannot be used as an everyday camera

DSLR

- Useful for everyday photography as well as astroimaging
- Doesn't require additional filters as a one-shot colour camera
- Takes images with a large field of view
- Cheaper than a CCD
- Large sensors often leave stars distorted at the edges of a frame

Long exposures and filters can produce amazing photo results

© ESO; Raymond Gilchrist; Jathin Nithin; Ian Sharp; Roehus Hess

WHAT'S IN THE SKY?

What to look out for during this observing period

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29 DECEMBER
Conjunction between the Moon and Jupiter in Pisces

29 DECEMBER
The Moon and Jupiter make a close approach, passing within 2°02' of each other in Pisces

29 DECEMBER
Open cluster NGC 2244 is well placed for observation at +4.8 in Monoceros

1 JANUARY
The Moon and Uranus make a close approach, passing within 39.3" of each other in Aries

1 JANUARY
The Moon will pass in front of Uranus, visible from parts of Europe and Canada

2 JANUARY
Open cluster Messier 41 is well placed for observation at magnitude +4.5 in Canis Major

3 JANUARY
Conjunction between the Moon and Mars in Taurus

3 JANUARY
The Moon and Mars make a close approach, passing within 31.4" of each other in Taurus

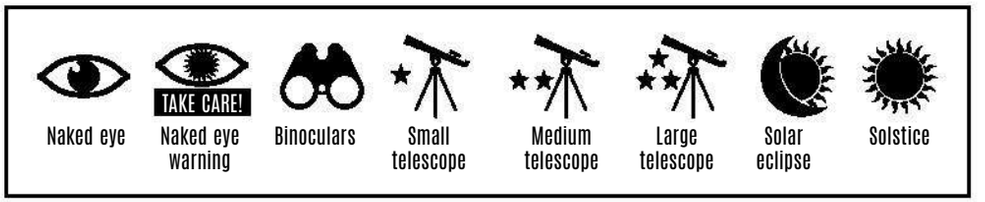
3 JANUARY
The Moon will pass in front of Mars, visible from parts of Africa and the Maldives

15 JANUARY
Open cluster Messier 47 is well placed for observation, glowing at magnitude +4.4 in Puppis

15 JANUARY
Spiral galaxy NGC 2403 is well placed for observation, glowing at +8.9 in Camelopardalis

19 JANUARY
The Gamma Ursae Minorid meteor shower reaches its peak

Red-light friendly
In order to preserve your night vision, you should read our observing guide under red light



3 JANUARY
The Quadrantid meteor shower reaches its peak

12 JANUARY
Comet C/2022 E3 ZTF will make its closest approach to the Sun, predicted to reach +7.9

12 JANUARY
Mars will reach the end of retrograde motion, ending its westward movement

"Comet C/2022 E3 ZTF will make its closest approach to the Sun, predicted to reach a magnitude of +7.9"

21 JANUARY
Mercury is at its highest altitude in the morning sky, dazzling at magnitude -0.2

22 JANUARY
Uranus will reach the end of retrograde motion, ending its westward movement

24 JANUARY
Mercury reaches half phase in the morning sky

26 JANUARY
Conjunction between the Moon and Jupiter in Pisces

26 JANUARY
Asteroid 6 Hebe is well placed for observation, glowing at magnitude +8.7 in Cancer

26 JANUARY
The Moon and Jupiter make a close approach, passing within 1°48' of each other in Pisces

© ESA/Hubble: Wiki/ Stephen Rahn

Jargon buster

Conjunction
An alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

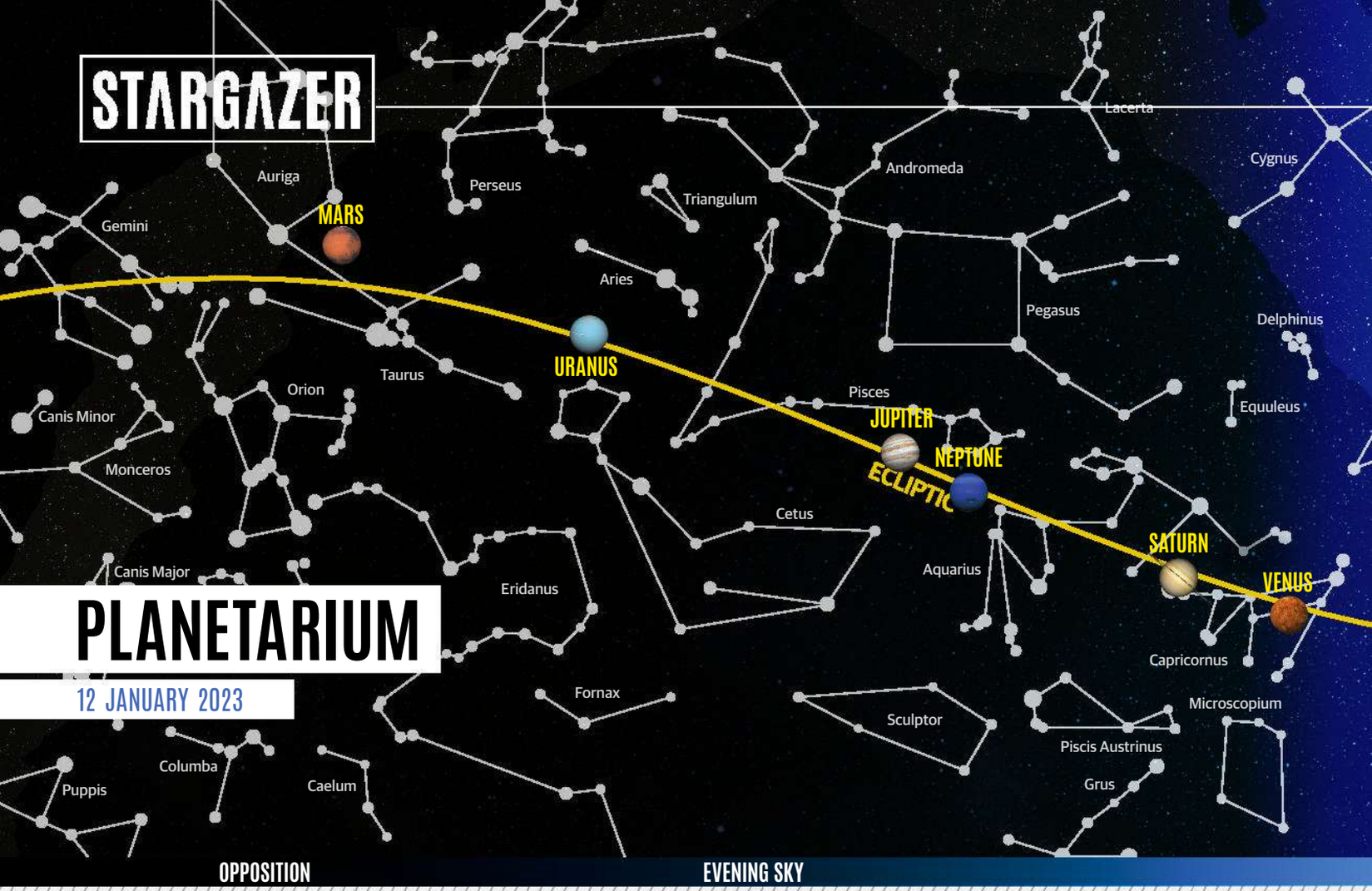
Declination (Dec)
How high an object will rise in the sky. Like Earth's latitude, Dec measures north and south in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and 60 arcminutes in a degree.

Opposition
When a celestial body is in line with Earth and the Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Right Ascension (RA)
RA is to the sky what longitude is to Earth, corresponding to east and west. It's measured in hours, minutes and seconds, as since Earth rotates on its axis, we see different parts of the sky throughout the night.

Magnitude
An object's magnitude tells you how bright it appears from Earth, represented on a numbered scale. The lower the number, the brighter the object. A magnitude of -1.0 is brighter than +2.0.

Greatest elongation
When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongation and as morning stars during western elongation.



MOON CALENDAR

* The Moon does not pass the meridian on 6 January

29 DEC	30 DEC	31 DEC	1 JAN
46.7%	57.7%	68.1%	77.4%
11:51 --:--	FQ 00:00 12:04	01:18 12:17	02:34 12:31

2 JAN	3 JAN	4 JAN	5 JAN	6 JAN	7 JAN	8 JAN
85.3%	91.6%	96.2%	99.0%	FM --.--%	99.8%	98.8%
03:51 12:49	05:06 13:11	06:19 13:40	07:24 14:20	08:20 15:11	09:03 16:13	09:34 17:22

9 JAN	10 JAN	11 JAN	12 JAN	13 JAN	14 JAN	15 JAN
95.9%	91.3%	85.1%	77.5%	68.7%	58.9%	TQ 48.5%
09:58 18:33	10:16 19:45	10:30 20:57	10:43 22:08	10:54 23:20	11:05 --:--	00:34 11:18

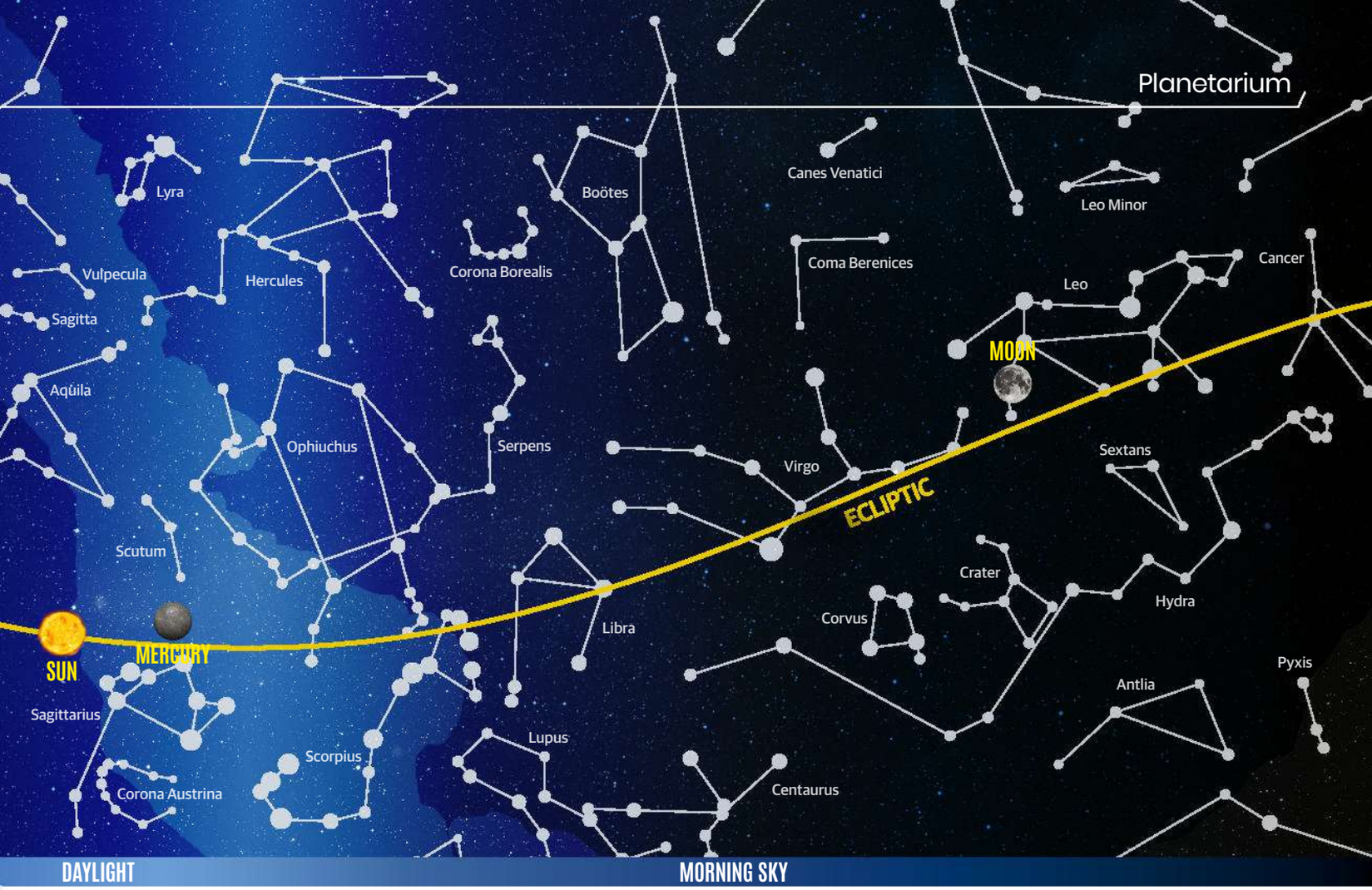
16 JAN	17 JAN	18 JAN	19 JAN	20 JAN	21 JAN	22 JAN
37.7%	27.1%	17.3%	9.1%	3.3%	NM 0.4%	0.9%
01:53 11:34	03:16 11:54	04:43 12:24	06:08 13:07	07:22 14:11	08:17 15:35	08:55 17:09

23 JAN	24 JAN	25 JAN	26 JAN
4.6%	11.2%	19.9%	29.9%
09:22 18:43	09:41 20:14	09:56 21:40	10:10 23:02

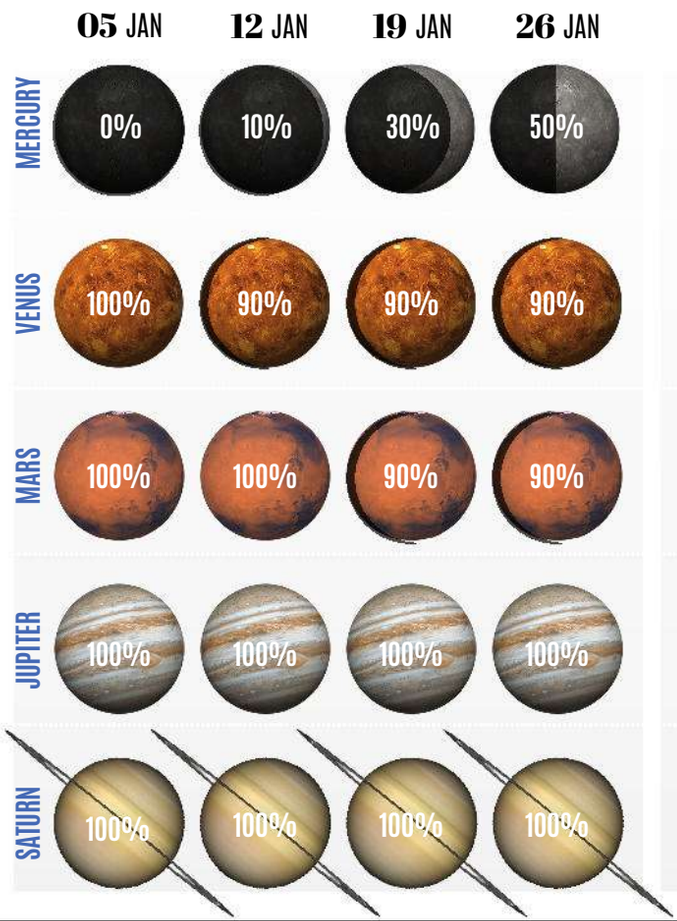
% Illumination
Moonrise time
Moonset time

FM Full Moon
NM New Moon
FQ First quarter
TQ Third quarter

All figures are given for 00h at midnight (local times for London, UK)



ILLUMINATION PERCENTAGE



PLANET POSITIONS

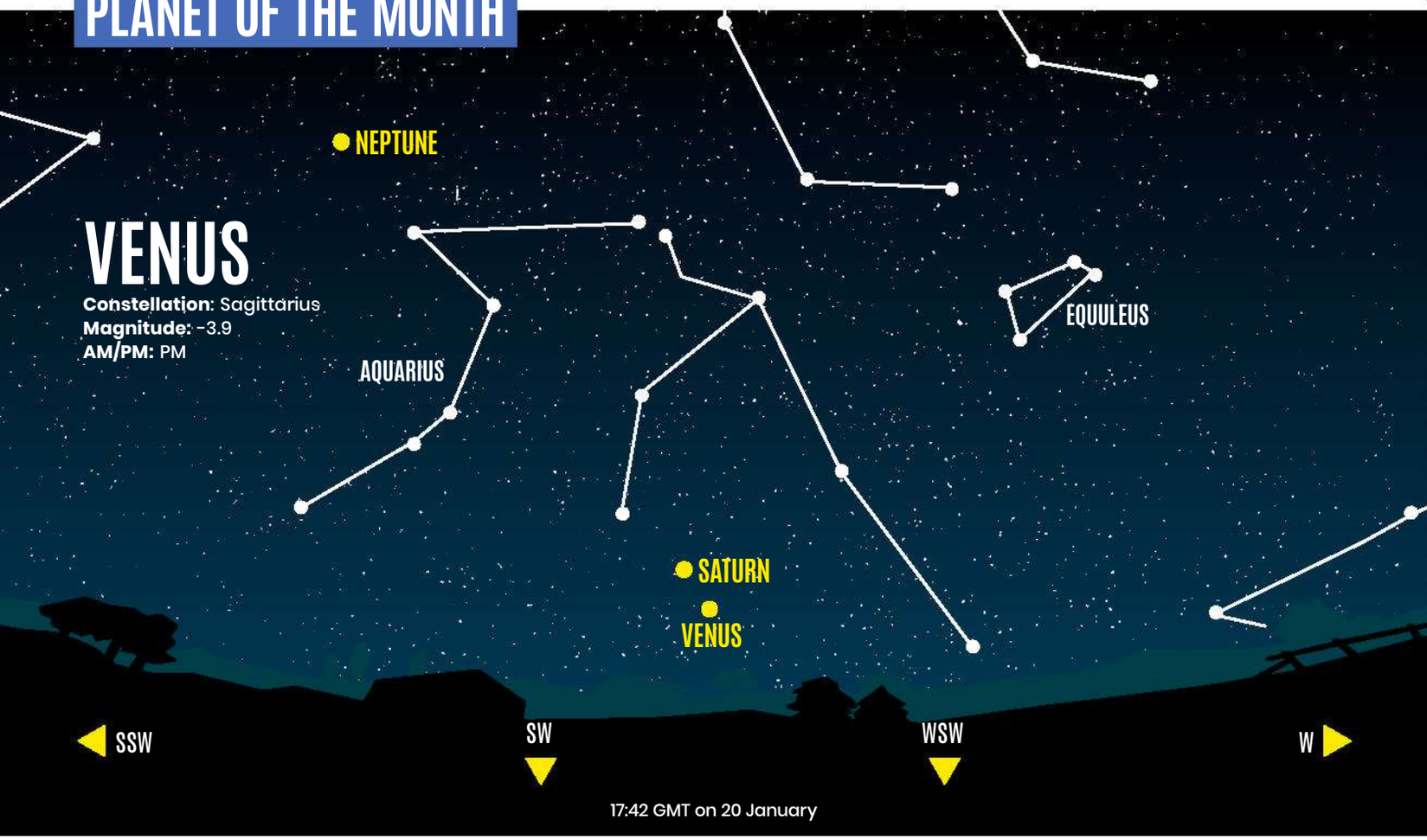
All rise and set times are given in GMT

DATE	RA	DEC	CONSTELLATION	MAG	RISE	SET
29 DEC	19h 43m 40s	−21° 21' 07"	Sagittarius	+0.2	09:07	17:19
5 JAN	19h 24m 47s	−19° 50' 57"	Sagittarius	+3.9	08:11	16:42
12 JAN	18h 47m 09s	−19° 37' 51"	Sagittarius	+2.6	07:05	15:38
19 JAN	18h 33m 22s	−20° 20' 48"	Sagittarius	+0.3	06:28	14:53
26 JAN	18h 47m 12s	−21° 16' 24"	Sagittarius	−0.1	06:21	14:33
29 DEC	19h 41m 33s	−22° 43' 10"	Sagittarius	−3.9	09:15	17:07
5 JAN	20h 18m 43s	−21° 06' 58"	Capricornus	−3.9	09:13	17:28
12 JAN	20h 54m 54s	−19° 00' 26"	Capricornus	−3.9	09:08	17:50
19 JAN	21h 30m 01s	−16° 27' 26"	Capricornus	−3.9	09:00	18:13
26 JAN	22h 04m 05s	−13° 32' 17"	Aquarius	−3.9	08:50	18:36
29 DEC	04h 28m 33s	+24° 35' 41"	Taurus	−1.3	13:29	06:24
5 JAN	04h 23m 53s	+24° 28' 21"	Taurus	−1.1	12:58	05:50
12 JAN	04h 22m 08s	+24° 24' 41"	Taurus	−0.9	12:29	05:21
19 JAN	04h 23m 08s	+24° 25' 20"	Taurus	−0.6	12:03	04:54
26 JAN	04h 26m 41s	+24° 30' 15"	Taurus	−0.4	11:38	04:31
29 DEC	00h 03m 59s	−00° 59' 00"	Pisces	−2.4	11:34	23:31
5 JAN	00h 07m 04s	−00° 37' 05"	Pisces	−2.4	11:08	23:09
12 JAN	00h 10m 37s	−00° 12' 19"	Pisces	−2.3	10:42	22:47
19 JAN	00h 14m 34s	+00° 15' 02"	Pisces	−2.3	10:16	22:26
26 JAN	00h 18m 55s	+00° 44' 43"	Pisces	−2.2	09:50	22:05
29 DEC	21h 38m 22s	−15° 24' 52"	Capricornus	+0.8	10:25	19:50
5 JAN	21h 41m 06s	−15° 11' 04"	Capricornus	+0.8	09:59	19:26
12 JAN	21h 44m 00s	−14° 56' 26"	Capricornus	+0.8	09:33	19:03
19 JAN	21h 47m 02s	−14° 41' 03"	Capricornus	+0.8	09:07	18:40
26 JAN	21h 50m 10s	−14° 25' 04"	Capricornus	+0.8	08:41	18:17

THIS MONTH'S PLANETS

Venus takes pride of place in the evening sky as we head into the New Year

PLANET OF THE MONTH



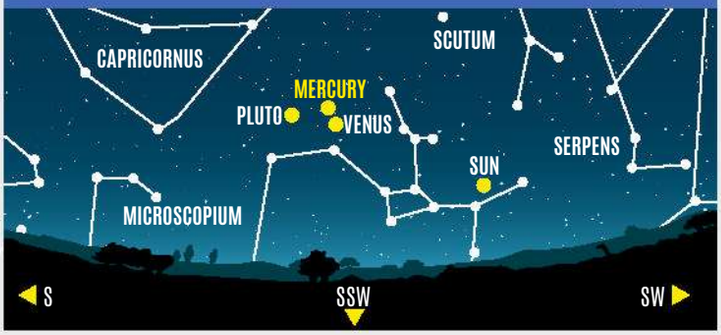
Mars has been our planet of the month for the past few issues, but now it has started to fade and pull away from Earth again, another planet can enjoy the spotlight. During the month ahead, Venus will be a lovely sight in the western sky after sunset, an 'evening star' very obvious to the naked eye as a bright silvery-blue spark shining above the roofs and treetops as soon as darkness falls. And it will have company, too.

On the evening of 29 December you'll see a fainter 'star' very close to Venus, to its upper right. This will be Mercury, the closest planet to the Sun, and on that evening the two worlds will be less than two degrees – or four Moon widths – apart in the sky. They'll look like a double star to the naked eye, and will be even more beautiful through binoculars or a small telescope. However, they will be low in the southwest as the sky darkens, and if you have trees, buildings or hills on your skyline in that direction they may obscure them. If you want to see this cosmic close encounter in all its glory, you'll need to find somewhere with a clear view to the southwest. As the days pass the two planets will appear to move apart, with Mercury dashing quickly towards the Sun, leaving Venus shining on its own. Its visibility will improve a little each evening, and by 15 January Venus won't be setting until two hours after the Sun, giving you plenty of time to enjoy seeing it shining in the twilight.

During January Venus will have another planetary close encounter – this time with Saturn. By the middle of January bright Venus and fainter Saturn will be approaching each other until they have a planetary meeting on the evening of 22 January, when they will be just half a degree, or a Moon width, apart. Again the pair will be low in the southwest, so you might need to travel somewhere with a clear view, but it will be worth it. They'll look beautiful through binoculars and small telescopes.

The following evening Venus and Saturn will have moved noticeably further apart, but they will be joined in the twilight by a beautiful, thin crescent Moon. Together these three objects will make a very attractive grouping, and astrophotographers everywhere will be trying to capture them with their cameras. The camera on your phone should be good enough for you to take your own picture of them.

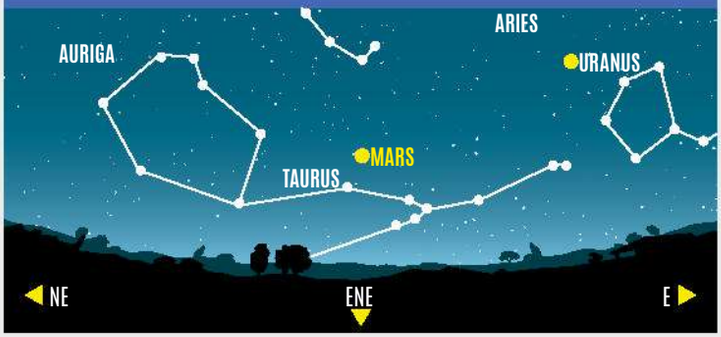
MERCURY 15:00 GMT on 28 December



Constellation: Sagittarius **Magnitude:** +0.5 **AM/PM:** PM

At the end of December Mercury will be an 'evening star' shining very close to much brighter Venus. The pair will be low in the southwest after sunset. On the evening of 29 December Mercury and Venus will be less than two degrees – that's four Moon widths – apart, and the pair will look very attractive in binoculars and small telescopes.

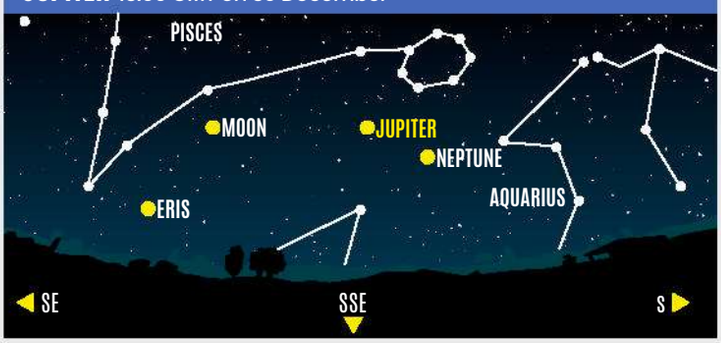
MARS 16:00 GMT on 30 December



Constellation: Taurus **Magnitude:** -1.3 **AM/PM:** PM

All through the coming month you'll see Mars shining between Taurus' famous Hyades and Pleiades star clusters, its orange hue in striking contrast to the electric blues and silvery whites of the stars in those clusters. At the end of January Mars will have faded to magnitude -0.4, but will still be very obvious to the naked eye.

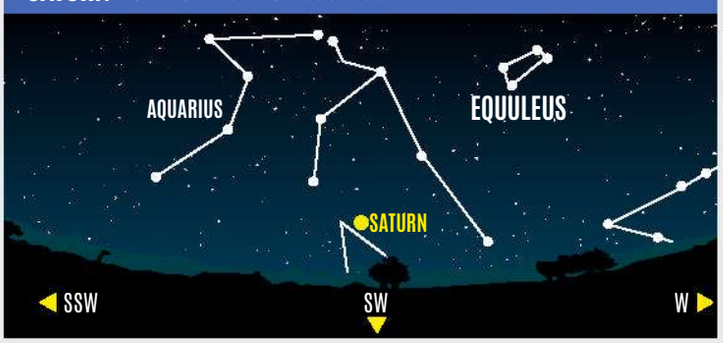
JUPITER 16:00 GMT on 30 December



Constellation: Pisces **Magnitude:** -2.4 **AM/PM:** PM

As January approaches, Jupiter will be a bright blue-white 'evening star' shining halfway up in the sky above the southern horizon as twilight begins and setting around midnight. But as January begins, Jupiter's visibility will worsen. It will set a little earlier each night until it sets around 20:00 by the end of the month.

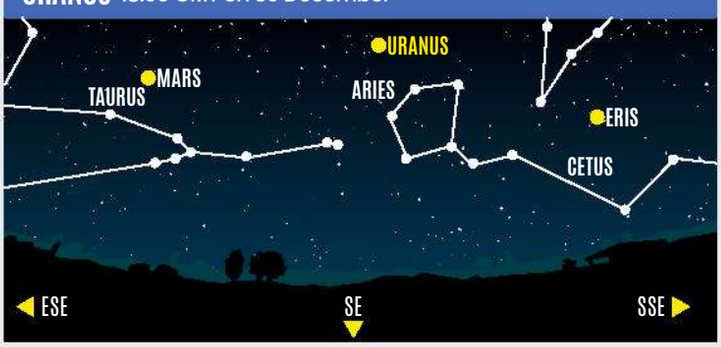
SATURN 19:00 GMT on 29 December



Constellation: Capricornus **Magnitude:** +0.8 **AM/PM:** PM

Saturn will already be low in the southwest at sunset, and will set itself not long after. In mid-January Saturn will have a close encounter with much brighter Venus. The two will be closest together on the evening of 22 January, when they will be less than half a degree – the width of the Moon – apart.

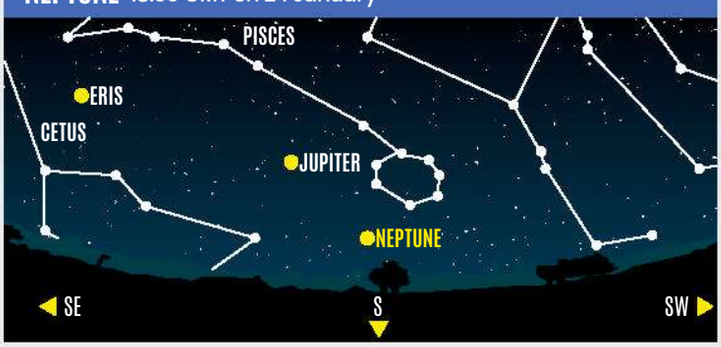
URANUS 18:00 GMT on 30 December



Constellation: Aries **Magnitude:** +5.7 **AM/PM:** PM

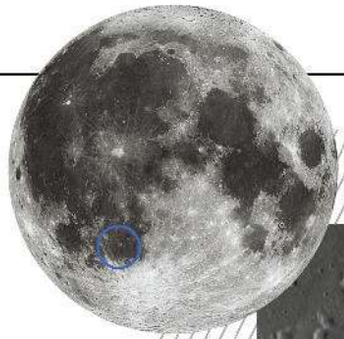
Uranus will be an evening object this coming month. At the end of December it will be visible from sunset right through the early hours of the next morning, not setting until around 04:00. You'll find it in the star-starved constellation of Aries, to the right of much brighter Mars and the sparkling Pleiades star cluster.

NEPTUNE 18:00 GMT on 24 January



Constellation: Aquarius **Magnitude:** +7.9 **AM/PM:** PM

Neptune, the farthest planet from the Sun, will be an evening object during the month ahead, but you'll need a pair of binoculars or a small telescope to see it. You'll find it close to much brighter Jupiter in the evening sky, looking like a tiny, blue-green star just eight degrees away from it.



MOON TOUR

WOLF

Finding this lunar crater won't leave you howling with frustration on cold January nights

Many people don't realise that the full Moons seen throughout the 12 calendar months have names, often rooted in nature. These can be traced back to before the Julian calendar was followed and have ties to Native American culture. For example, May's full Moon is the 'Flower Moon'. In November the 'Hunter's Moon' shines over our Bonfire Night celebrations, and as December ends, late-night Christmas shoppers scurry around looking for last-minute gifts beneath the 'Cold Moon'.

This January, the full Moon that will illuminate our frosty grass and windscreens and the snowmen slumping in our gardens is known as the 'Wolf Moon', named by Native Americans after the mournful howling of hungry wolves searching for food halfway through winter. Wolves are in quite short supply in the UK these days, but there is one place you can guarantee seeing one this month – on the Moon itself. Our Moon tour destination this month is the small crater 'Wolf'.

Named after the accomplished German astronomer Max Wolf – who discovered several comets and supernovae, proved dark nebulae were clouds of interstellar dust and discovered no fewer than 248 asteroids in his lifetime – Wolf crater is 26 kilometres (16 miles) wide and not quite a kilometre deep, making it one of the smaller craters we've visited on our long tour. It lies almost in the centre of Mare Nubium, the 'Sea of Clouds', a roughly circular dark stain on the Moon which can be found to the southeast of the much larger Oceanus Procellarum. The crater was photographed by the crew of Apollo 16 in 1972, who landed in the Descartes Highlands region, and was imaged again more recently, but in much higher resolution, by the Lunar Reconnaissance Orbiter's cameras.

Although it's small itself, Wolf can be found quite easily because it lies halfway between two larger, more obvious craters: Bullialdus to its upper left and Pitatus to its lower right. Far too small to be seen with the naked eye and a challenge with a pair of binoculars, Wolf looks nothing like a wolf. Through a telescope's low-power eyepiece it appears as a roughly heart-shaped feature. Higher magnifications reveal a gap in Wolf's southern rim which makes it look more like a small vase or the Greek 'Omega' symbol than a heart.

Wolf's walls are relatively featureless, are thicker and wider in some places than others and its floor is dark and flat with a short, curved chain of four small secondary craters on its western side. The most remarkable thing about Wolf is probably the bright apron of ejecta that spreads out from its sides and bottom, like an open cloak. Look at that through your telescope's highest magnification eyepiece and you'll see it is very rugged and hummocky, spattered with its own small craters. It looks like a small part of the lunar highlands surrounding the crater.

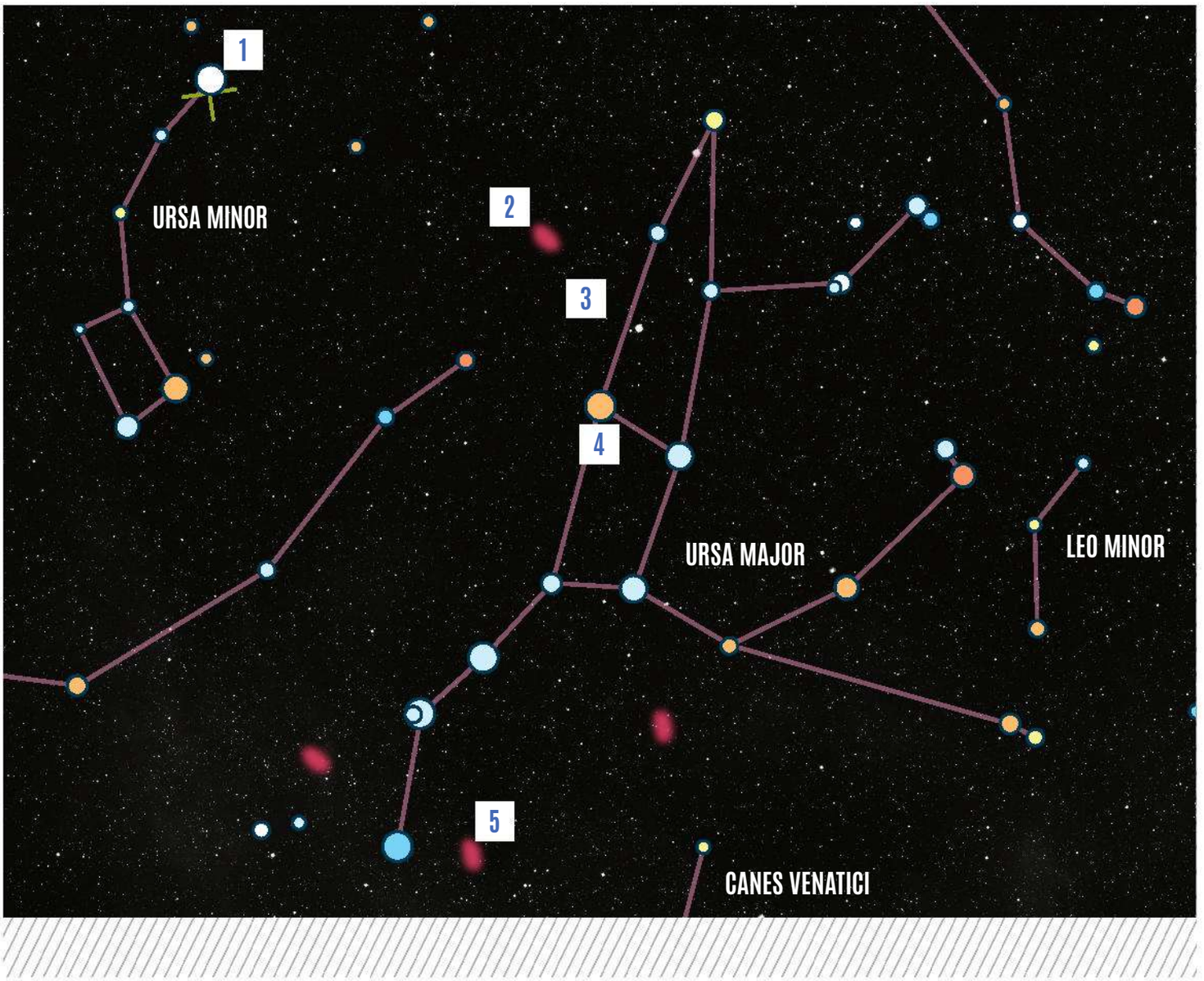
So when can you see this crater for yourself? At the very start of our observing period, Wolf isn't visible, totally hidden in shadow. However, by the evening of 1 January the terminator will have swept over the crater like a dark tsunami, and Wolf will be illuminated from the east. This will be a good time to look for details and small features on its floor and that surrounding ejecta apron as they are lit up by the slanting rays of the low Sun. Wolf will remain fully illuminated between 1 and 15 January, but by 16 January the terminator will have rolled over it again and it will have vanished, shrouded in darkness once more and not reappearing until next month.

While Wolf might not be the most striking or dramatic crater on the Moon, it is definitely worth a look at through your telescope. It's a valuable reminder that the Moon has a lot more to offer the observer than the 'celebrity' features like Copernicus, Tycho and the Sea of Tranquillity.

© NASA

TOP TIP!

Be sure to zoom in on Wolf when it is near the terminator – you'll see much more detail in and around it.



NAKED EYE AND BINOCULAR TARGETS

How to see sparkling stars and distant misty galaxies this month

1 Polaris (Alpha Ursae Minoris)

Also known as the 'Pole Star', Polaris is the star everything else in the northern sky appears to wheel around as the Earth turns. With a magnitude of +1.97, it's fainter than many people think, but it stands out because there are few other bright stars close to it in the sky.

2 Bode's Galaxy (Messier 81)

Messier 81 is a beautiful spiral galaxy more than 12 million light years away from us. At magnitude +6.9, it's too faint for the eye to see, but can be seen as a tiny, misty oval through good binoculars on a dark night.

3 Merak (Beta Ursae Majoris) and Dubhe (Alpha Ursae Majoris)

This close pair of bright, blue-white stars in the bowl of the Big Dipper is used by stargazers to help them find the Pole Star in the sky. An imaginary line drawn between the two and extended beyond them points straight through to Polaris.

4 The Cigar Galaxy (Messier 82)

Glowing at a faint magnitude of +8.4, you'll need a sky with no light pollution and a Moonless night to find the tiny smudge of light that is Messier 82. This starburst galaxy is roughly 12 million light years away.

5 The Whirlpool Galaxy (Messier 51)

This famous galaxy is nicknamed the Whirlpool Galaxy because of its beautiful Catherine-wheel shape in photographs. Messier 51 can be seen in binoculars as a faint, round smudge just off the end of the handle of the Big Dipper.

4 Christmas Tree Cluster (NGC 2264)

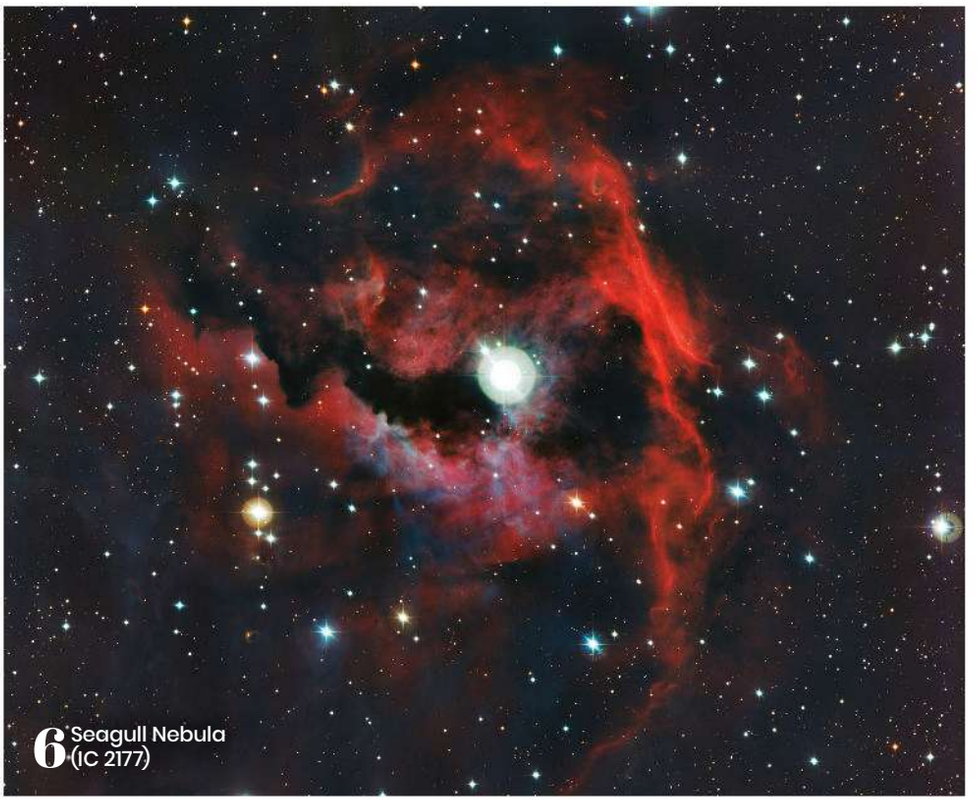
DEEP SKY CHALLENGE

OBSERVE THE UNICORN'S SPARKLING TREASURES

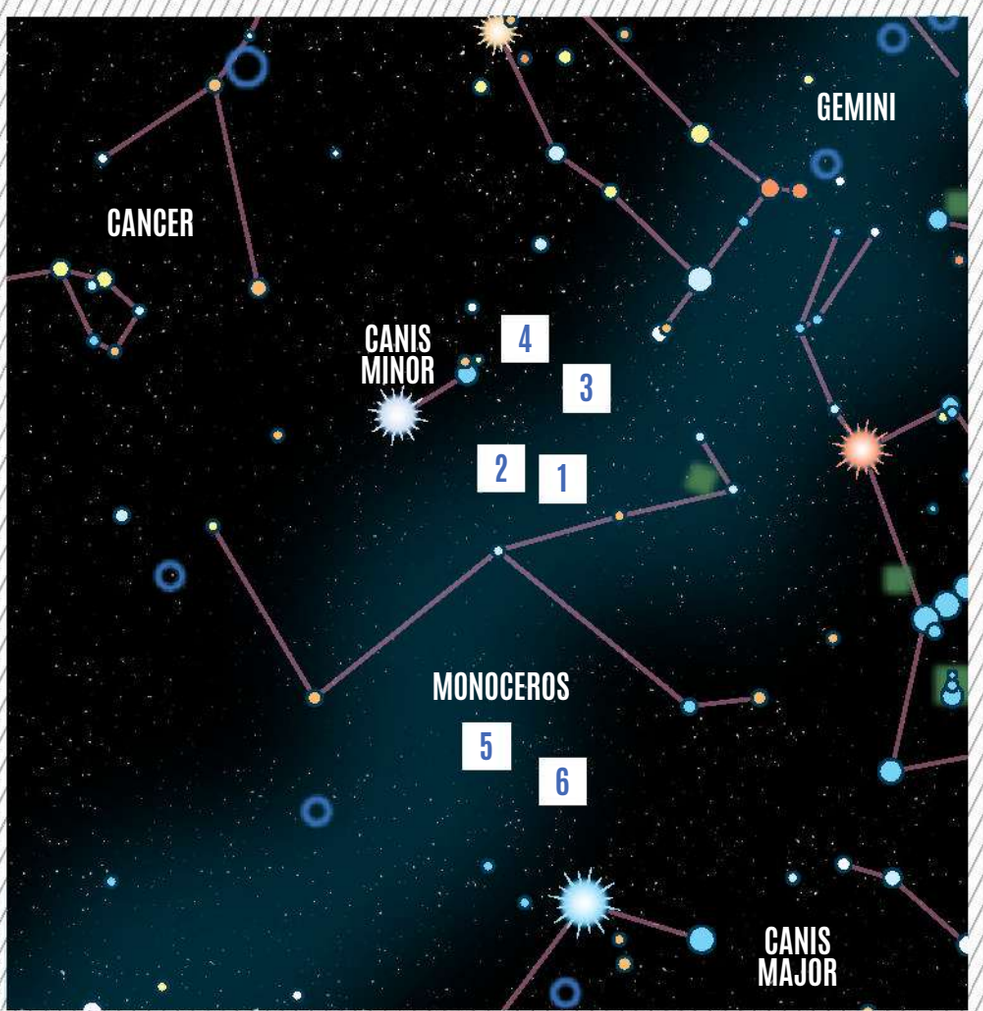
Winter skies are rich in deep-sky objects for your telescope to hunt down and enjoy. Here are just a select few

Just to the east of the constellation of Orion (the Hunter) is a dimmer constellation called Monoceros (the Unicorn). Although none of the stars that make up the group are particularly bright, this constellation sits in the band of the Milky Way, and is therefore rich in nebulae and star clusters. It contains some fairly well-known objects, such as the Cone Nebula, the more famous Rosette Nebula and Hubble's Variable Nebula. This is a rich region of the sky to go exploring with a telescope of almost any size.

3 Hubble's Variable Nebula (NGC 2261)



6 Seagull Nebula (IC 2177)



1 Rosette Nebula (NGC 2238)
The Rosette Nebula is a tricky one to see visually. However, with the right equipment, namely a larger aperture and very good observing conditions, it opens up to reveal a fine cluster at the heart of luminous gas and dust.

2 Satellite Cluster (NGC 2244)
You can observe this loose collection of stars with just a pair of binoculars, but for more comfortable views use a small telescope to pick out the gaggle of blue stars that shine at a collective magnitude of +4.4.

3 Hubble's Variable Nebula (NGC 2261)
You'll need at least a four-inch telescope in order to spot this mysterious-looking object. The nebula itself is like a hollow shell, but see if you can spot light and dark knots using a high-power eyepiece.

4 Cone Nebula (NGC 2264)
Since the Cone Nebula is a challenging target given its feeble glow, dark skies and a large-sized telescope are needed to pick it out. The nebula lies in the southern portion of the Christmas Tree Cluster, also designated NGC 2264.

5 Heart-Shaped Cluster (Messier 50)
This is an open star cluster that, as its name suggests, appears to have the shape of a heart. A small telescope will reveal the cluster's heart shape, while larger apertures will tease out blue-white, yellow and orange stars within.

6 Seagull Nebula (IC 2177)
This nebula is best seen in large-aperture telescopes, and an ultra-high contrast (UHC) filter can help increase the contrast. This H II complex lies on the border of Monoceros and Canis Major, covering over three degrees of sky.

© NASA; ESO

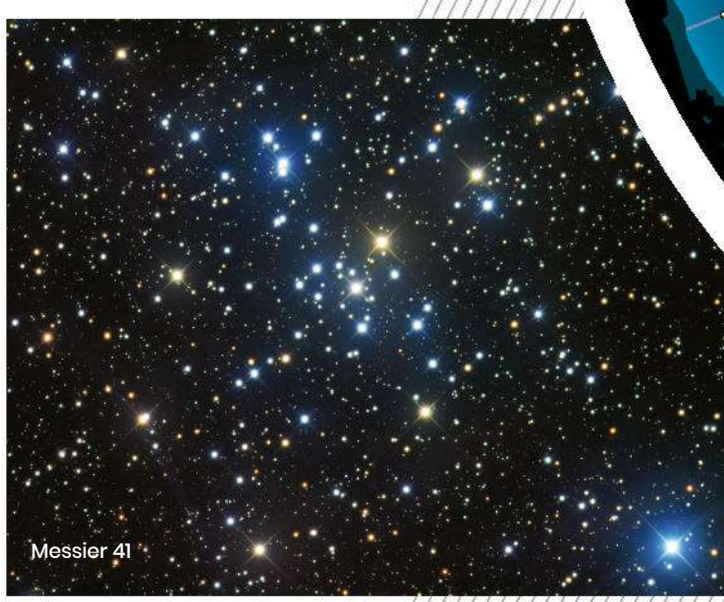
THE NORTHERN HEMISPHERE

The New Year has arrived, with some of the very best night-sky targets

Whether you just got your first telescope for Christmas or you've long been observing, there are some wonderful targets to seek out in the New Year. Orion (the Hunter) and Taurus (the Bull) remain prominent in the sky, offering splendid sights including red supergiant Betelgeuse, brilliant blue-white Rigel, the Pleiades star cluster (Messier 45), orange giant Aldebaran and, of course, the Crab Nebula (Messier 1). Look southeast and you'll spot a celestial Great Dog: a seemingly basic-looking pattern of stars, Canis Major features several binary systems and supergiant stars. It's also home to open cluster Messier 41, which contains an impressive collection of red giants and white dwarfs, sitting not too far from the bright 'Dog Star' Sirius.

Waxing gibbous Moon

Betelgeuse (Alpha Orionis)


Messier 41

Using the sky chart

This chart is for use at 22:00 mid-month and is set for 52 degrees latitude.

1. Hold the chart above your head with the bottom of the page in front of you.
2. Face south and notice that north on the chart is behind you.
3. The constellations on the chart should now match what you see in the sky.

Magnitudes

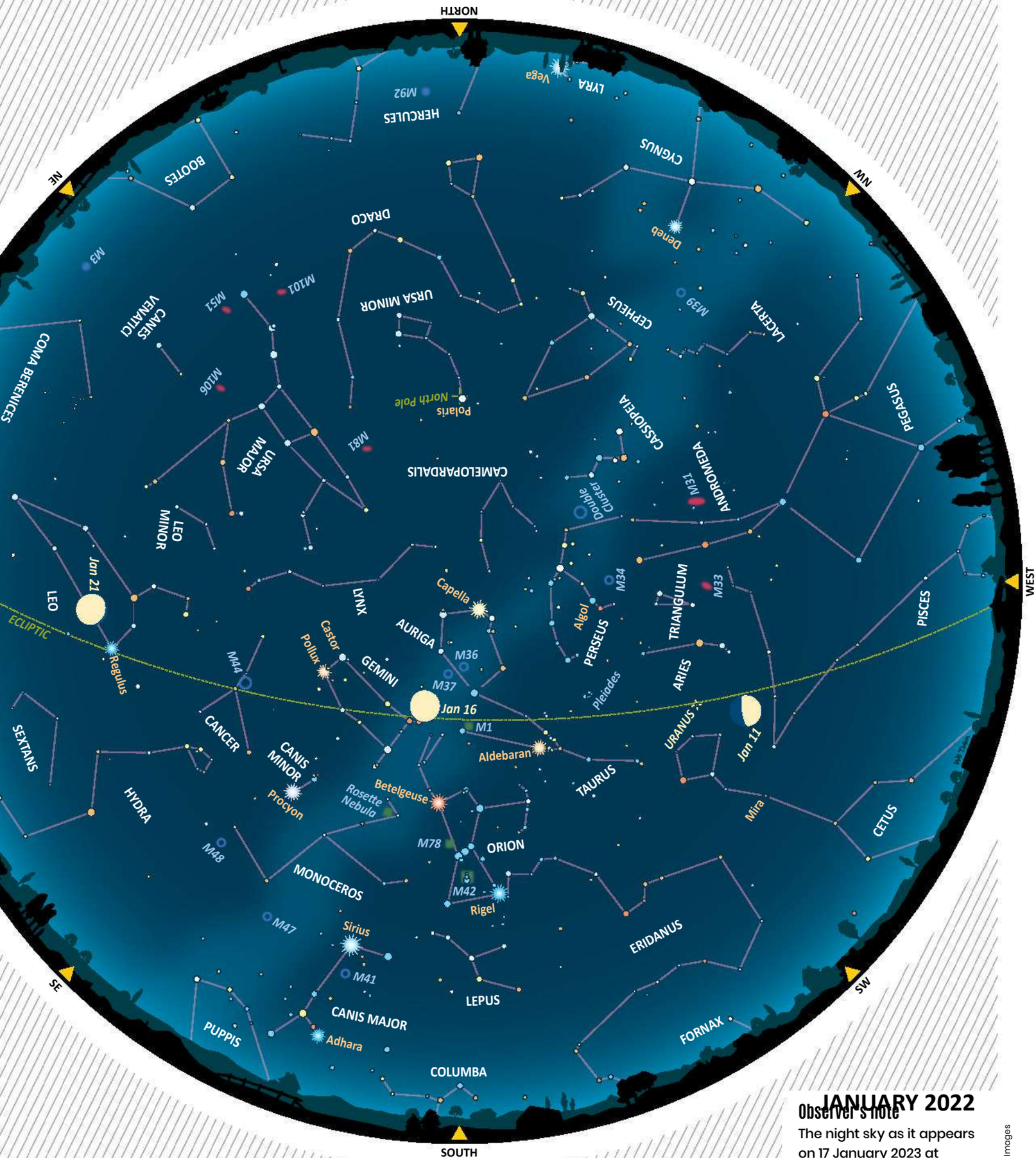
- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to +0.5
- +0.5 to +1.0
- +1.0 to +1.5
- +1.5 to +2.0
- +2.0 to +2.5
- +2.5 to +3.0
- +3.0 to +3.5
- +3.5 to +4.0
- +4.0 to +4.5
- Fainter
- Variable star

Spectral types

- O–B
- A
- F
- G
- K
- M

Deep-sky objects

- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies



JANUARY 2022

Observer's note

The night sky as it appears on 17 January 2023 at approximately 22:00 (GMT)

© Getty Images

ASTROSHOTS OF THE MONTH

BASUDEB CHAKRABARTI

Location: Yousmarg, Kashmir

"Deep-scape images line up a deep-sky object as it is rising or setting over an earthly landscape. This image was created on the same night, from the same tripod position, using the same lens. What it means is these are true-to-life representations of amazing celestial objects in relation to our Earth. We're not able to see this level of detail with our eyes, but are blessed to be able to capture it via cameras. No matter the night, no matter the place, no matter what you can see, you're never truly alone. The night sky is full of amazing objects, and this connects amazing deep-sky objects to our amazing Earth."

Lunar eclipse

SOUMYADEEP MUKHERJEE

Location: West Bengal, India

"I planned to do an HDR image of the lunar eclipse since I got to know that the eclipse would be visible from my location. I'm glad that the final image came out almost as I had imagined it to be. The other image (inset) captures the last few moments of the eclipse. This was my first time seeing and photographing a lunar eclipse and I'm glad that the weather turned well enough at the last moment to catch a glimpse of this beautiful phenomenon."

OLLIE TAYLOR

Location: Mount Teide, Tenerife

"I had driven up to the top of Mount Teide night after night, mapping out where was best for the very small window within which to be able to shoot the most prominent part of the Milky Way during my time in Tenerife in April. I had gone there knowing that the timing window was very small in which to achieve my shots; still, that hadn't stopped me from driving around the mountaintops from sunset onwards looking for the best compositions. Then one night, about two hours after sunset, I was fortunate enough to witness this zodiacal light bursting through the low cloud cover on the horizon with the Teide volcano in the distance."

A beautiful starscape and zodiacal light

REVIEW

SKY-WATCHER EXPLORER 130

A Newtonian reflector that's versatile, affordable and optically impressive with an equatorial mount to view Solar System objects, double stars and deep-sky targets

Reviewed by Jamie Carter

The Sky-Watcher Explorer 130 has something most affordable telescopes lack. It ships with an equatorial mount that, when aligned with Earth's axis – something that's extremely easy to do – allows it to more easily track objects as they appear to move across the night sky. Since most affordable telescopes can be tricky to precisely position, this gives it an immediate advantage over the competition. This Newtonian reflector also has plenty of aperture and good-quality optics that make it a good beginner's telescope for exploring brighter deep-sky objects as well as the Moon and planets. However, the Explorer 130 does have a learning curve that's steeper

TELESCOPE ADVICE

Cost: £199 (approx. $242.75)

From: Sky-Watcher

Type: Newtonian reflector

Aperture: 5.12"

Focal length: 25.59"

Focal ratio: f/6.9

Total kit weight: 12.6 kilograms

Mount type: German equatorial (EQ2)

"This Newtonian reflector also has plenty of aperture and good-quality optics that make it a good beginner's telescope"

than its simpler rivals. Here's what you need to know about the Explorer 130.

At its core, this is a Newtonian reflector telescope with an aperture of 130mm, which is about the minimum required to begin exploring the deep sky. Don't be scared off by its equatorial mount. It's not as intuitive as the alt-azimuth mounts that almost all beginner telescopes use, largely because it goes beyond merely manipulating the telescope up or down (altitude) and left or right (azimuth). However, it's a much better mount for a telescope than an alt-azimuth. An equatorial mount has the same two axes, but one of them has a polar axis tilted so that it's parallel to Earth's axis. If you use it in the Northern Hemisphere then it needs aligning to Polaris, the North Star, with a dial on the side for the user to set for the latitude of the observing site. For example, for London it's 51 degrees, for New York it's 41 degrees and for Los Angeles it's 34 degrees.

It's not immediately intuitive to use and the instructions that come with the Explorer 130 aren't that great, but it's worth persevering with to get it set up properly. Earth rotates quickly, meaning that any object you get in your eyepiece will soon drift out of it. With the Explorer 130 aligned to exactly how the night sky moves, it's easy to follow objects on or near the ecliptic – like the Moon and the planets – just by manipulating a couple of fine hand controls on the Explorer 130. Slewing from object to object is easier and faster, too, because the mount gives a lot of freedom of movement.

Like many other affordable telescopes, the Explorer 130 is primarily aimed at those wanting to get good views of the Moon, planets and brighter deep-sky objects such as star clusters and galaxies, but it does have a few advantages over the competition. Aside from its equatorial mount, the Explorer 130's reasonably long tube length and resulting f/7 rating make it possible to go to reasonably high magnifications – for once the inclusion of a Barlow lens actually makes sense. Although it never gets much beyond what we expect at this price point, we were able to pop the Barlow lens on with the included 25mm eyepiece for 75x magnification and reasonably sharp views of the Jovian system, with Jupiter's moons easily visible as bright worlds clustered on one side of the giant planet.

Saturn's rings also looked impressive, though that Barlow lens does introduce some distracting chromatic aberration, or false colour. We got good, clear views of the Double Cluster in the constellation of Perseus, while with the included 10mm eyepiece on the Barlow lens, creating 150x magnification, we were easily able to split the blue and gold stars that make up Albireo in the constellation of Cygnus.

But don't plan on taking the Explorer 130 anywhere. If you master the equatorial mount and set it up, you're basically done. When its mount, tube and tripod are set up it's just too big and heavy to then take it down and travel to dark skies. Although not impossible, we think

BEST FOR...

- £ MEDIUM BUDGETS
- PLANETARY VIEWING
- BEGINNERS
- BRIGHT DEEP-SKY OBJECTS

The equatorial mount is a real draw, but isn't the best quality

The telescope's usefulness can be expanded with more eyepieces

the Explorer 130 is likely going to stay in one place, and it's best stored in its ready-to-observe configuration. So make sure you have significant spare room before buying the Explorer 130.

The equatorial mount on the Explorer 130 is a step up in terms of functionality and versatility compared to an alt-azimuth, but in terms of quality it's only just about adequate. It represents an initially steep learning curve that not all users will be happy to take, not only in how the mount actually works but also in finding objects using right ascension and declination. These coordinates are the space equivalent of longitude and latitude coordinates on Earth, and they're expressed in degrees and hours and minutes. It's worth the time to get to know how the equatorial mount works, and we guarantee you'll never want a non-equatorial telescope again.

However, the Explorer 130 isn't the best equatorial mount available. It's something of a surprise to find an equatorial mount on a telescope of this low price, but it's not a shock to discover that the equatorial mount on the Explorer 130 suffers from a fairly basic build. Although the freedom of movement it gives is excellent, it's not as precise as it could be. The fine hand controls work well, but the rig isn't as steady as it could be and can't be locked into position as reliably or steadfastly as required for total accuracy. The average quality of the bearings means the Explorer 130's equatorial mount shouldn't be over-tightened. That said, at this very low price, we're pleased with the mount's overall build and performance.

For the price being asked, we think the Explorer 130 is a good-value telescope capable of some impressive views of the Moon, planets and bright deep-sky objects. Its mount may make it seem a little complicated, but it's not too difficult to master and it's worth it for the ease of moving the telescope and keeping it trained on planets and the Moon. That mount and its manual design means some knowledge of the night sky – and the willingness to learn about sky coordinates – is required, while the Explorer 130's weight makes it a telescope to use in one place.

© Jason Parnell-Brookes

FOR

- An affordable equatorial mount
- Good optics
- Slow-motion controls
- Low price

AGAINST

- Heavy, so difficult to transport
- Basic red dot finder
- Equatorial mount lacks precision
- Manual targeting

The telescope comes with a 25mm and a 10mm eyepiece, providing magnifications of 53x and 132.5x

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IN THE SHOPS: DEEP-SPACE TELESCOPES

Use one of the best telescopes for deep space to tour the universe

Celestron NexStar 8SE

Cost: £1,499 (approx. $1,832.15)
From: Celestron

1 One of the most striking things about the Celestron NexStar 8SE is its compact and practical size, despite offering a long focal length. The body is clutter-free, so you can easily pick it up and transport it to where it's needed without worrying about breaking anything or accidentally snapping things off. It's fairly heavy, but that gives it a robust and sturdy feel – much appreciated when we're spending this sort of money. The telescope is controlled using an in-built hand controller. We also liked the feeling of using the hands-on controller with tactile, easy-to-use buttons rather than having to rely on a smartphone app. Astrophotographers taking long exposures will love the smooth and accurate tracking thanks to the high-quality motorised functionality. Although it is quite a sizable financial investment, this thing is built to last and will easily see you through decades of stargazing enjoyment, thus being excellent value for money.

Sky-Watcher Skyliner 200P Classic Dobsonian

Cost: £379 (approx. $463.20)
From: Sky-Watcher

2 The Skyliner 200P is the most affordable way to enjoy deep-sky astronomy at this standard. Its basic Dobsonian mount can't find or track objects in the sky for you, but with smooth mechanics, you'll have no trouble doing this by hand the old-fashioned way. The 50-millimetre finder, a small telescope in its own right, is ideally suited to finding and centring objects of interest before investigating them with the sizable main mirror. The telescope also features a dual-size focuser that can accept two-inch eyepieces, a must for anyone seeking the most immersive deep-sky views. While it's somewhat bulky at nearly 24 kilograms, the Skyliner 200P has a fairly small footprint of about 54 centimetres (21 inches), fitting neatly into tight storage spaces when parked vertically. It's a superb-value proposition for those on a budget looking to do serious deep-sky work.

Celestron Advanced VX 8" EdgeHD

Cost: £2,549 (approx. $3115.50)
From: Celestron

3 The EdgeHD employs a widely acclaimed optical tube assembly as the basis for a very capable overall system. The StarSense camera not only aligns the telescope for you, but also connects to Celestron's SkyPortal app via the telescope's onboard Wi-Fi. This is all powered by a substantial rechargeable battery built into the mount – no cables or external power supply required. All this comes at a cost, but if you want a home observatory that sets itself up and takes you on a tour of the sky, it's a fair price. The Schmidt-Cassegrain is expensive for its aperture, but it's extremely compact, employing two mirrors and a corrector plate to fold its long focal length into a shorter tube. The EdgeHD optics are among the best in class at this price point, and this tube assembly is well suited to astrophotography with the right accessories.

"it's great value and provides surprisingly bright views of diffuse targets"

Unistellar eVscope 2

Cost: £3,999 / $4,899
From: Unistellar

4 The eVscope 2 – the newer version of the eQuinox – offers a very different way to 'see' the night sky. As a beginner, you can navigate the night sky in no time. The eVscope 2 uses a camera instead of an eyepiece, similarly to the original eQuinox, but it also has a Nikon eyepiece which will appeal to purist astronomers and clubs who don't want to 'see' the sky through the Unistellar app on a smartphone. It is straightforward to navigate the night sky at the touch of a button, even with no prior astronomy knowledge. In Explore mode, the app will recommend celestial objects based on your location and time zone. You need your phone or smart device to operate the telescope, so ensure you've charged both up before exploring. If you're looking for highly detailed images for large prints, consider a traditional telescope, as the 7.7-megapixel resolution is somewhat lacking compared to the resolution you can get from DSLR and mirrorless cameras.

Sky-Watcher Stargate 500P SynScan GoTo Dobsonian

Cost: £5,299 (approx. $6,476.65)
From: Sky-Watcher

5 Sky-Watcher's Stargate 500P is a 20-inch-aperture colossus that brings a top-tier viewing experience to serious deep-sky observers. With a truss tube design, the telescope is relatively lightweight and can be set up or taken down piece by piece by a single person in as little as 20 minutes. With a DC plug or external power tank, the telescope can find and track objects in the sky with reasonable accuracy via the Sky-Watchers SynScan computer handset. Dual-encoder technology allows you to manually slew the telescope by hand without having to realign it – as both axes continue to record their position, you can quickly jump from object to object with tracking enabled. It's a monster telescope that offers the ultimate deep-sky viewing experience – there's nothing like the sight of a galaxy or nebula with such a large mirror under dark skies.

Sky-Watcher Heritage 114P Virtuoso

Cost: £239 (approx. $292.10)
From: Sky-Watcher

6 Despite its diminutive size and light weight, the Heritage 114P isn't lacking in features. It offers the whole Newtonian reflector experience, with the added benefit of being able to automatically counteract the rotation of Earth and track the sky. With the mount's AA battery or DC-powered motors switched on, you can smoothly slew across the sky using the built-in controls and then steadily keep your object of interest in the field of view. The tabletop Dobsonian mount can be upgraded at any time with Sky-Watcher's SynScan GoTo handset. This can find more than 40,000 objects in the sky for you – useful for tracking down those very faint sights that don't readily jump out. The Heritage 114P is on the smaller side for a Newtonian reflector. Still, it's great value within this affordable price range and provides surprisingly bright views of diffuse targets like nebulae and galaxies.

HEROES OF SPACE

WERNHER VON BRAUN

The father of rocket science went from working for the Nazis to becoming an American space hero

Wernher Magnus Maximilian Freiherr von Braun was born on 23 March 1912 in the town of Wirsitz in Poland. He was part of an aristocratic family, with his father serving as minister of agriculture during the Weimar Republic and his mother having royal ancestry across Europe. His mother gave him a telescope at a young age, inspiring his passion for astronomy, while his love of rocketry was apparent from the age of 12 when he accidentally blew up a firework-powered toy car in a crowded street.

Von Braun and his family moved to Germany following World War I. It was at school in Weimar, and later on the island of Spiekeroog, that von Braun took up physics and mathematics to learn more about rocket engineering. In 1932 he graduated from the Technical University of Berlin with a degree in aeronautical engineering, and two years later he gained a PhD in physics from the Humboldt University of Berlin.

While studying for his PhD, von Braun began working as a rocket engineer for the German Army at the age of just 21. He became integral to the army, and during the 1930s von Braun and his team successfully built and launched rockets that flew a few kilometres high. By 1944 the German Army had a working V-2 rocket, which they used to devastating effect against the Allies. Around this time, von Braun realised that Germany wouldn't win the war and began making procedures to transfer to the US. In a daring escape in 1945, von Braun led his team from the German rocket facility at Peenemünde to American forces and duly surrendered.

Von Braun and his team were taken to the US in what was known as Operation Paperclip. He was employed by the US Army for 15 years developing ballistic missiles, but in 1960 he transferred to the newly created NASA. He was first tasked with developing the unmanned Mercury-Redstone program before starting work on the development of the Saturn rockets. After the successful manned Mercury and Gemini projects, von Braun's long-standing dream of seeing humans walk on the Moon was realised when, launching atop his Saturn V rocket, the crew of Apollo 11 ventured to the lunar surface in July 1969.

Von Braun retired from NASA in 1972 at the culmination of the Apollo program, joining the aerospace company Fairchild Industries in Maryland. A few years later he helped establish the National Space Institute – now known as the National Space Society – before being diagnosed with cancer and passing away on 16 June 1977 at the age of 65.

ALL ABOUT SPACE ISSUE 139

ON SALE 26 JANUARY

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ALL ABOUT SPACE

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Printed by William Gibbons & Sons Limited, 26 Planetary Road, Willenhall, Wolverhampton, West Midlands, WV13 3XB

Distributed by Marketforce, 5 Churchill Place, Canary Wharf, London, E14 5HU www.marketforce.co.uk Tel: 0203 787 9060

ISSN 2050-0548

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